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ABSTRACT

Project SOAR (Stress on Analytic Reasoning) is a pre-college summer program for natural, health, and mathematics science majors jointly developed and conducted by the Departments of Biology, Chemistry, Mathematics/Computer Science and Physics/Pre-Engineering at Xavier University of Louisiana. The program objective was to increase performance in and reduce attrition from entry-level science and mathematics courses. Project SOAR is comprised of three components: (1) Piagetian laboratory experiments to improve general problem-solving skills; (2) specific instruction to improve those analytical reasoning/reading skills needed to perform well on standardized exams; and (3) vocabulary building. This notebook contains the 20 three-hour laboratory experiments, each organized as a learning cycle. The experiments, five each from Biology, Chemistry, Mathematics and Physics, were developed as units of four each to be completed during a given week. The fifth day of each of the five working weeks is devoted to instruction in simple BASIC programming. (Author/DS)

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XAVIER UNIVERSITY OF LOUISIANA

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PROJECT SOAR

(Stress On Analytical Reasoning)

**A Cooperative Effort by
the Departments of Biology, Chemistry,
Mathematics/Computer Science, and
Physics/Pre-Engineering**

at

Xavier University of Louisiana

to

**Facilitate the Acquisition of
Problem Solving Skills**

1981

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Xavier University of Louisiana

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Preface

Project SOAR (Stress On Analytical Reasoning) is a pre-college summer program for natural, health, and mathematical science majors jointly developed and conducted by the Departments of Biology, Chemistry, Mathematics/Computer Science, and Physics/Pre-Engineering at Xavier University of Louisiana. The primary objective of the program is to increase performance in and reduce attrition from entry-level mathematics and science courses. The program is one component of a comprehensive, cooperative effort by XU's science departments to make science-related careers more accessible to the Black Americans for which the University was founded. As such, both SOAR and the related academic-year programs are direct extensions of the Xavier's overall philosophy of "standards with sympathy"--coupling high academic expectations with mechanisms which allow disadvantaged students to attain success.

Project SOAR is comprised of three components--Piagetian-based laboratory experiments to improve general problem-solving skills, specific instruction to improve those analytical reasoning/reading skills needed to perform well on standardized exams, and vocabulary building.

This notebook contains the twenty, three-hour laboratory experiments, each of which is organized as a Piagetian-based "learning cycle" containing exploration, invention, and application phases. The experiments, five each from Biology, Chemistry, Mathematics, and Physics were developed as units of four each to be completed in any order during a given "week." The fifth day of each of the five working weeks of Project SOAR is devoted to instruction in simple BASIC programming.

Additional information about Project SOAR may be obtained from the following sources:

Overall: C. Eric Lincoln. "From Concrete to Abstract Reasoning: SOAR Plots the Course," 6th Report on Teaching, Change, August, 1978.

Piagetian-Based Laboratories:

JW Carmichael, Jr., Jacqueline Hunter, Johnette Hassell, Lester W. Jones, Mary Ann Ryan, and Harold Vincent. "Project SOAR (Stress On Analytical Reasoning): A Multidisciplinary Summer Program for Minority Science Freshmen," The American Biology Teacher, Vol. 42, No. 3, 169 (March, 1980).

(continued)

Analytical Reasoning/Reading Skills:

Arthur Whimbey, JW Carmichael, Lester W. Jones, Jacqueline Hunter, and Harold Vincent, "Teaching Critical Reading and Analytical Reasoning in Project SOAR," Journal of Reading, Vol. 24, No. 1, 5 (October, 1980).

Related Activities at Xavier:

JW Carmichael, Jr., Mary Ann Ryan, and Arthur Whimbey, "Cognitive Skills-Oriented PSI in General Chemistry for Improved Success of Educationally-Disadvantaged Students," Journal of Developmental and Remedial Education, Vol. e, No. 2, 4 (Winter, 1979).

Mary Ann Ryan and JW Carmichael, Jr., "A Piagetian-Based General Chemistry Laboratory Sequence for Science Majors," Journal of Chemical Education, Vol. 57, No. 9, 642 (October, 1980).

JW Carmichael, Jr., et. al., General Chemistry Laboratory Manual (Piagetian-based), Stipes Publishing, Champaign, IL, 1981.

Individuals to Contact for further detail:

- ...For Mathematics/Computer Science, Lester W. Jones, Chairman, Department of Mathematics/Computer Science.
- ...For Physics/Pre-Engineering, Harold Vincent, Chairman Department of Physics/Pre-Engineering.
- ...For Biology, Chemistry, and Pre-Health Professions, JW Carmichael, Jr., Professor of Chemistry and Pre-Health Professions Adviser.

Note: It is expected that instructors using this notebook will have access to a related Instructor's Manual and will have completed a Workshop on Science on Science Teaching and the Development of Reasoning. Workshop materials are available at a moderate fee from the Reasoning Laboratory, Lawrence Hall of Science, University of California, Berkeley, California 94720.



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Project SOAR

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**This experiment is a modification of one developed in the ADAPT Program at the University of Nebraska--Lincoln by Robert Fuller, Director.*

FACTORS AFFECTING THE BREATHING RATE IN GOLDFISH

Exploration

A goldfish has been placed at your station. Observe its activity for a few minutes. Note the movements of its mouth and of its opercula. The operculum is a covering over the gills, one on each side of the fish. The more rapidly the fish moves water over its gills, the more rapidly the opercula will move back and forth (i.e., "open" and "close"). This is the principle gas exchange mechanism of the fish. The fish will tend to absorb dissolved oxygen from the water and discharge some of its CO_2 into the water as the water passes over its gills surfaces. Try to time this opening and closing of gills in numbers per minute to get the breathing rate.

The following materials should be in your area:

timing device (wall clock may be used)
large beaker of fresh aquarium water
crushed ice
*beaker of boiled and cooled aquarium water
beaker of hot aquarium water (do not put fish in)
cover for beaker
thermometer
**soda siphon

*water has been boiled and cooled in order to reduce the concentration of dissolved O_2 .

**may be used to pump CO_2 into water.

Use the materials to investigate some of the factors that affect the "breathing" rate in fish.

(Return the fish to its original beaker after each exposure to an experimental environment. Allow the fish time to recover).

Data

Environment

Breathing Rate

Invention

You are to participate in a group discussion concerning your observations. Use the space below to make general statements about the effects of different environments on the breathing rate in fish.

Application

1. Using temperature as your environmental factor, subject your fish to temperatures that range from 10° - 35°C . Plot the breathing rate versus temperature on a sheet of graph paper.
2. Subject your fish to various volumes of water. Plot the breathing rate versus volume of water on a sheet of graph paper.
3. How would the breathing rate be affected if four more fish were added to the water?

RATES OF CHEMICAL REACTIONS

Exploration

Students may work in pairs for this experiment.

1. Obtain 10 ml of KIO_3 (potassium iodate) solution in a 250 ml beaker. In another beaker, obtain 10 ml of sodium bisulfite solution and add 1 ml of starch solution to it. Now pour the potassium iodate solution into the sodium bisulfite solution that had the starch added to it. Stir the combined solution with a stirring rod and observe carefully until you note a change.

Record your observations here.

2. When you mixed the solutions of KIO_3 and NaHSO_3 together, a chemical reaction took place. The appearance of the blue color marked the completion of the reaction. (Starch is present as an indicator which is necessary for the blue color to appear.) The length of time it takes from the mixing of the solutions to the appearance of the blue color is, therefore, a measure of the reaction rate; i.e., how fast the reaction takes place.

We have available in the laboratory the following solutions of potassium iodate, sodium bisulfite, and starch:

KIO_3	NaHSO_3	starch
1 gram/liter	1.0 gram/liter	1 gram/100 ml
2 gram/liter	2.0 gram/liter	2 gram/100 ml
3 gram/liter	3.0 gram/liter	
4 gram/liter	4.0 gram/liter	

Experiment with various combinations of these solutions to see whether the reaction time is affected by the use of the different solutions. Keep a careful record of the combinations you use. You may either make your own data table or use the one on the following pages.

3. Reaction Rates

	Solution used	Concentration of solution	M1 Used	Reaction Time
Reaction 1				
Reaction 2				
Reaction 3				
Reaction 4				
Reaction 5				

3. Reaction Rates (continued)

	Solution used	Concentration of solution	Ml Used	Reaction Time
Reaction 6				
Reaction 7				
Reaction 8				
Reaction 9				
Reaction 10				

3. Reaction Rates (continued)

	Solution used	Concentration of solution	M1 Used	Reaction Time
Reaction 11				
Reaction 12				
Reaction 13				
Reaction 14				
Reaction 15				

3. Reaction Rates (continued)

	Solution used	Concentration of solution	Ml Used	Reaction Time
Reaction 16				
Reaction 17				
Reaction 18				
Reaction 19				
Reaction 20				

3. Reaction Rates (continued)

	Solution used	Concentration of solution	ML Used	Reaction Time
Reaction 21				
Reaction 22				
Reaction 23				
Reaction 24				

INVENTION

1. What combination of solutions made the reaction go fastest (i.e., gave the shortest reaction time)?
2. What combination of solutions made the reaction go slowest (i.e., gave the longest reaction time)?
3. Based on your data, what factors appear to affect the rate of the reaction?
4. List specific reasons why you believe the factors in (3) to be influential. Cite appropriate data to support your reasons.
5. Compare your data with other members of the class. Do your conclusions agree with theirs? If not, what differences appear in the methods used and in the data obtained.

APPLICATION

1. Study the effect of temperature on the rate of the reaction between KIO_3 and NaHSO_3 . Describe the procedure you use, the data you obtain, and the conclusions you draw from the data. Use the following pages for recording information.
2. Study the effect of light on the rate of this reaction. Describe the procedure you use, the data you obtain, and the conclusions you draw from the data. Use the following pages for recording information.

RELATIVE SIZES OF FRACTIONS

Introduction To Fractions

Your instructor will provide you with pieces of circular construction paper. You will be asked to "cut" the paper into slices. Read the directions written on the reverse of your piece of construction paper before you proceed. Then answer the following questions in the space provided.

1. How many equal pieces did you cut your "pie" into?
2. What fraction of the "pie" does one of the pieces represent?
3.
 - a) Choose a friend and see how many pieces he cut his "pie" into.
 - b) What fraction would represent each of his pieces?
4. How many pieces would a "pie" have if each one was represented by the fraction $\frac{1}{3}$.
5. If we cut 3 "pies" into slices of $\frac{1}{3}$ each, how many slices would we have altogether.
6. How many sixteenths are there in 1?

When you finish get one of your instructor's approval before you continue.

Exploration

You probably have seen fractions before and if you're like most people, they don't exactly turn you on. Today you will learn one way to attack fractions that will help you conquer them.

There are several pieces of construction paper on the table today which are cut to resemble pieces of a pie. You are to examine these and collect your data in the table on page 2. Choose one color to collect and record your data on the next page.

LIST YOUR DATA IN ORDER OF INCREASE SIZE BY COPYING THE FRACTIONS ON THE NEXT PAGE. EQUAL FRACTIONS ARE TO BE WRITTEN ON THE SAME LINE WITH "=" BETWEEN THEM.

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COLOR #1 ()	COLOR #2 ()

Choose two slices of the same color and with the same numerator. (The numerator of a fraction is the top number.) Write your choices below and write the proper symbol ($<$ or $>$) between them. Do the same for two fractions of the same color and the same denominator. (The denominator is the bottom number.)

FRACTIONS WITH SAME NUMERATOR

FRACTIONS WITH SAME DENOMINATOR

When you finish, show your work to your instructor before continuing.

Invention

1. What rule can you state about the relative sizes of fractions with equal numerators? Write this in words and illustrate with examples from your data.
2. Circle the larger of the fractions in each group below (use the rule from #1):
a) $3/5$, $3/10$ b) $16/23$, $16/34$ c) $5/8$, $5/17$
3. State a rule about the relative sizes of fractions with equal denominators list some examples from your data illustrating this.
4. Circle the smaller of the two fractions in each group below: (use the rule in #3):
a) $3/5$, $4/5$ b) $5/22$, $7/23$ c) $10/51$, $9/51$
5. Return to the data on page 2 and choose a group of slices which are all the same size.
6. Choose the fraction in the group in #5 which has the smallest denominator. Write it down and show how each of the other fractions in the group in #5 can be derived by arithmetic from this one.

When you finish, show your work to your instructor before continuing.

7. State a rule which explains the results of #6.
8. a) Use your answer in #7 to explain why $24/108 = 2/9$.
- b) Circle the one(s) of the following which equal $5/16$.
- $10/32$, $1/3$, $25/80$
9. Show how $5/16$ can be obtained from $25/80$ by performing the same arithmetical operation on both the numerator and denominator.
10. State a rule derived from the results of #9.

When you finish, show your work to your instructor before continuing.

Invention (continued)

You have seen that fractions have two numbers (numerators and denominators) the values of which can affect the size of the fraction. This part of our experiment with fractions will be an effort at organizing our results into a few rules which we can use when we don't have the cut-out slices to actually compare. Your instructor will help you collect your rules. You are to write them here.

Application

1. Classify the following fractions by placing them in order smallest to largest. Then check your results by changing each fraction to a decimal number using the calculator provided. Note that the decimal comparison is very easy as long as a calculator is handy. Try doing an expansion (division) by hand without the calculator. The rules above are easire to apply than division by hand!!!!

a) $1/15$, $5/63$ decimals:

b) $23/14$, $16/7$ decimals:

c) $1/5$, $6/29$, $4/21$, $3/14$ decimals:

2. Give an approximation (a fraction which has smaller numbers but is about the same size) to the following and show how the approximation compares to the original.

Example: $8/50 = \underline{\hspace{1cm}}$ Ans: $1/7 = 8/56 < 8/50 < 8/48 = 1/6$

a) $5/63 =$

b) $7/43 =$

c) $47/93 =$

When you finish, show your work to your instructor before continuing.

PERIODIC MOTION FOR FUN & PROFIT

Exploration

Equipment:

clamp
steel strips
small magnets
ruler
stopwatch
2" x 4" board

Clamp one end of the steel strip to a piece of furniture or 2" x 4" board, attach a magnet, and set it swinging.

List some properties of this system that might be affected by variations in other properties.

Now make measurements to determine quantitative relationships that seem to interest you. If you think of objects that you need which are not in your possession, ask for them.

Please record your observations and data in the space below.

TABLE 1

--	--	--	--	--	--	--

INVENTION

What conclusion(s) can you state based on your data?

Consult your nearest neighbors and find out what conclusions they have reached. If theirs are different from yours, perform a set of measurements, record your data in the table below, and state your opinion about their conclusions.

TABLE 2

--	--	--	--	--	--

APPLICATION

In this part of the exercise you are interested in determining those factors which affect the time that is required for a mass (body) at the end of a spring to vibrate a single time.

This time is called the period of vibration.

Equipment

2 springs
200-gm mass, 400-gm mass, 500-gm mass
1 meter stick
1 stopwatch

What is the best way to conveniently measure this time?

Which factors or properties of the system do you think will influence the period? As you think of them, write each at the head of a column in Table 3 on the next page.

Write in the space below the procedure that you will use in determining if and how each of the factors you listed does affect the period of vibration.

Now carry out the procedure. Record your data in Table 3.

TABLE 3

(Construct your own.)

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Look at the data in the table and see if you can determine which factors affected the period. Prove that the factors you indicated did affect the period.

If you have enough data, state what effect each factor had. If you do not have enough data, collect more and state the effects.

GEOLOGIC TIME

Exploration

In geologic history just as in human history it is necessary to have an established time scale so as to arrange the events of the past in chronological order. The following chart gives you this time scale.

Geologic Time Chart

<u>Eras</u>	<u>Periods</u>	<u>Duration in Years</u>	<u>Dominant Life</u>
Cenozoic	Recent	10,000	Man
	Pleistocene	1,000,000	
	Pliocene	6,000,000	
	Miocene	12,000,000	Mammals
	Oligocene	16,000,000	
	Eocene	20,000,000	
Mesozoic	Paleocene	5,000,000	
	Cretaceous	65,000,000	
	Jurassic	35,000,000	Reptiles
Paleozoic	Triassic	35,000,000	
	Permian	25,000,000	Amphibians
	Carboniferous	85,000,000	
	Devonian	50,000,000	Fishes
	Silurian	40,000,000	
	Ordovician	85,000,000	Invertebrates
Proterozoic	Cambrian	70,000,000	
	Upper Pre-cambrian	650,000,000	Primitive multi-cellular forms
Archeozoic	Lower Pre-cambrian	650,000,000	Unicellular forms

At your desk you will find a board, a meter stick, a calculator, some paints and paint brushes. You are to use these materials as well as the information from the chart above to produce on your board certain time lines that correspond to some landmark in time.

Invention

What is the length of your board?

What amount of space on your board would be occupied by each era? Record the measurements in the following chart.

Era	Duration in Years	Measurement of Space Representing era
<u>Cenozoic</u>		
<u>Mesozoic</u>		
<u>Paleozoic</u>		
<u>Proterozoic</u>		
<u>Archeozoic</u>		

At this point, let your instructor see your results.

Mark off the five eras on your board according to the measurements recorded above.

Paint each era a different color.

Application

If we were to draw time lines to represent the periods of the Cenozoic eras on our boards, how much space would:

1. the Paleocene Period occupy?
2. the Eocene Period occupy?
3. the Oligocene Period occupy?
4. the Miocene Period occupy?
5. the Pliocene Period occupy?
6. the Pleistocene Period occupy?

On your board, mark off and paint-in the Pleistocene Period (represents the time in history that man appeared).

THE BURNING OF MAGNESIUM IN AIR

Exploration

Cut a piece of magnesium ribbon about 15 cm long. Fold it as loosely as possible to fit into a crucible. Cover the crucible and weigh it with the cover and ribbon.

wt. crucible + cover + Mg = _____

wt. crucible + cover = _____

wt. Mg = _____

With the cover of the crucible slightly open to allow air in, heat the crucible strongly with a bunsen burner for about 5 minutes. Observe the reaction that takes place. When the reaction appears to be complete (you can lift the cover slightly with your tongs to see), allow the crucible and contents to cool. Then weigh it on the top-loading balance.

wt. crucible + cover + product = _____

wt. crucible + cover = _____

wt. product = _____

How does the weight of the magnesium ribbon compare with the weight of the product you obtained?

Do you have any guesses as to what the magnesium combined with, and what the product might be?

When you have finished the above, ask your instructor for page 2. It contains data similar to that you just obtained in the lab. One column shows the weight of magnesium (reactant), and the other shows the weight of product formed from the burning of magnesium. Add your data to the table in the place indicated.

Data Sheet
for
The Burning of Magnesium in Air

Weight of Magnesium		Weight of Product	
1.	Your data from lab:	1.	
2.	1.0g	2.	1.9g
3.	2.5g	3.	3.9
4.	0.1g	4.	0.17
5.	0.5g	5.	0.83
6.	5.0g	6.	8.1
7.	3.0g	7.	4.9
8.	1.5g	8.	2.6
9.	2.0g	9.	3.0
10.	6.0g	10.	9.9g

Invention

Based on the data in the table, what relationship exists between the initial weight of Mg and the final weight of product formed?

If this relationship holds generally, how much product would you expect to obtain if you started with twice as much magnesium as you used in the lab for your experiment?

How much product would you expect to obtain if you started with 10 grams of Mg?

Graph the weight of magnesium vs. weight of product.

According to your graph, if the quantity of magnesium doubles, what happens to the quantity of product obtained?

If the quantity of magnesium triples, what happens to the quantity of product obtained?

What type of proportionality does this suggest between quantity of starting material and quantity of product?

Calculate the slope and y-intercept of your graph.

Application

Use your graph to predict the weight of product you could obtain if 1.3 grams of magnesium were burnt.

Use your equation to predict the weight of product obtainable from 1.3 grams of magnesium.

Now predict the weight of product you could obtain from 150 grams of magnesium.

If you wanted to obtain 0.5 grams of product, how much Mg would you have to burn to obtain it?

If you wanted to obtain 500 grams of product, how much Mg would have to be burned to obtain it?

CLASSIFICATION OF PLANE FIGURES WITH 3 SIDES

Exploration

1. On the table in the classroom you will find a number of three-sided figures and some measuring instruments. Please state one obvious geometric characteristic that is common to all the three-sided figures on the table.
2. Among the three-sided figures provided there are different sets of figures that have at least two common geometric characteristics. Collect data from several sets of geometric figures. You may find the data table below helpful in organizing your results.

Figure #	smallest angle (1)	intermed angle (2)	largest angle (3)	smallest side (1)	intermed side (2)	largest side (3)

3. Now that you have measured the two variables (angles and sides) for the triangles, separate your data in #2 into two groups which have approximately the same values for one of these variables. Record the information for these two groups in the tables on the next page.

TRIANGLES IN GROUP #1

Figure #	angle (1)	angle (2)	angle (3)	side (1)	side (2)	side (3)	angle ratio 1/3	angle ratio 2/3	angle ratio 1/2	side ratio 1/3	side ratio 2/3	side ratio 1/2

TRIANGLES IN GROUP #2

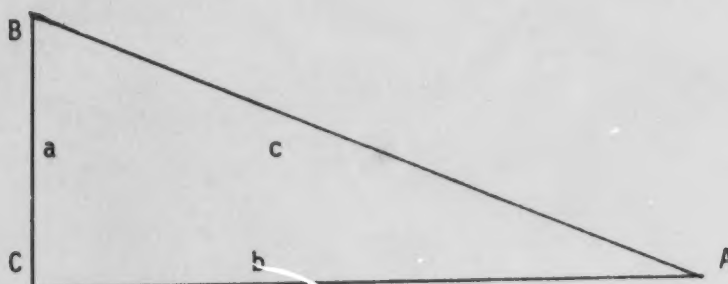
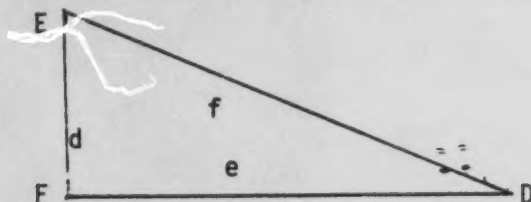
Figure #	angle (1)	angle (2)	angle (3)	side (1)	side (2)	side (3)	angle ratio 1/3	angle ratio 2/3	angle ratio 1/2	side ratio 1/3	side ratio 2/3	side ratio 1/2

4. Common characteristic did you notice after working #3?

When you finish this page, show your work to your instructor before continuing.

Invention

The right triangles shown below have each side and angle labeled.



5. Suppose that angles A & D are equal.

- How are angles B and E related?
- How are the angles of the triangles related?
- How are the ratios of the angles of the triangles related?
- How are the sides of the triangles related?
- How are the ratios of the sides of the triangles related?

6. Please expand on 5e above by writing down as many side ratios as you can for the two triangles. (For example, $a/c = d/f$). Check your answers with your instructor before proceeding.

7. We will make the following definitions with the ratios you discovered in #5 and #6.

The longest side of a right triangle is called the hypotenuse.
The longest side is always opposite the largest angle (the right angle.)

a) $\sin(A) = a/c = \frac{\text{side opposite angle A}}{\text{hypotenuse}}$

$$\sin(D) = d/f = \frac{\text{side opposite angle D}}{\text{hypotenuse}}$$

Sine of an angle is the ratio of the side opposite the angle to the hypotenuse of the right triangle.

b) $\cos(A) = b/c = \frac{\text{side adjacent to angle A}}{\text{hypotenuse}}$

$$\cos(D) = e/f = \frac{\text{side adjacent to angle D}}{\text{hypotenuse}}$$

Cosine of an angle is the ratio of the side adjacent to the angle and the hypotenuse.

c) $\tan(A) = a/b = \frac{\text{side opposite angle A}}{\text{side adjacent to angle A}}$

$$\tan(D) = d/e = \frac{\text{side opposite angle D}}{\text{side adjacent to angle D}}$$

Tangent of an angle is the ratio formed by dividing the length of the sides opposite the angle by the length of the side adjacent to the angle.

8. There are really three other possible ratios which can be formed using the lengths of the sides of the triangle. Write these down and we will give names to them.

9. There is at least one relationship between these six ratios which is easy to see. Find it.

When you finish, show your work to your instructor before continuing.

10. Find a paper $30^\circ - 60^\circ - 90^\circ$ triangle, and a $37^\circ - 53^\circ - 90^\circ$ triangle and a $45^\circ - 45^\circ - 90^\circ$ triangle from the given triangles. Measure the sides and calculate the sine, cosine, and tangent for each acute angle of each kind of triangle.

$30^\circ - 60^\circ - 90^\circ$

	Length of sides					
a	b	c		sine A	cosine A	tangent A

$45^\circ - 45^\circ - 90^\circ$

	Length of sides					
a	b	c		sine A	cosine A	tangent A

$37^\circ - 53^\circ - 90^\circ$

	Length of sides					
a	b	c		sine A	cosine A	tangent A

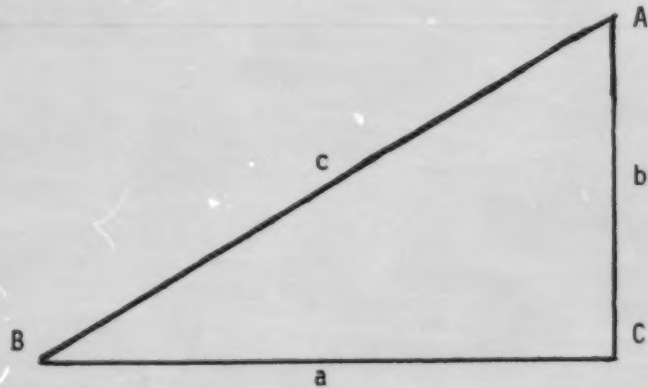
11. Find the trigonometric functions in the trigonometric tables provided or use a hand calculator. Read the values of sine, cosine, and tangent for 45° , 60° , and 37° . How do the values from the table or calculator compare with the ones you calculated in #8?

When you finish, show your work to your instructor before continuing.

Application

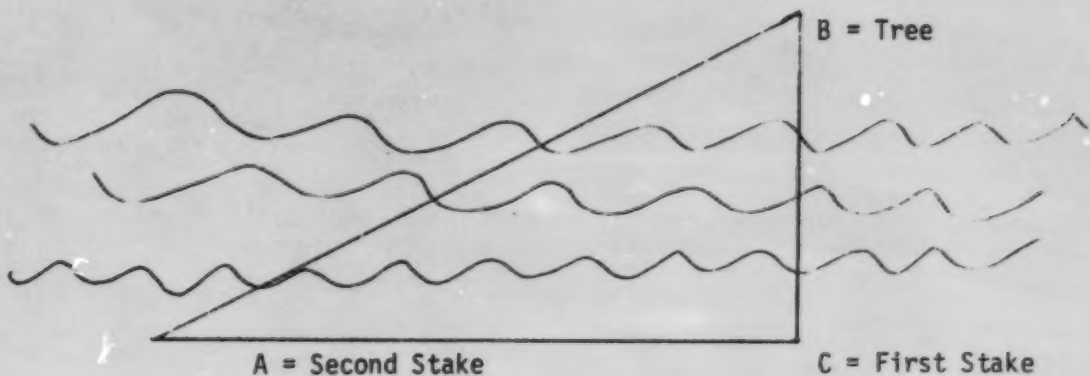
12. Assume that ABC is a right triangle, with the parts as labeled in the figure below. Find the unknown parts, given the following parts. Find angles measured to the nearest degree.

- a) $a = 5, b = 4$
Find c, A, B .
- b) $a = 17, B = 37^\circ$
Find b, c, A .
- c) $b = 8, B = 15^\circ$
Find c, a, A .
- d) $a = b$
Find c, A, B .



SHOW YOUR WORK BELOW AND ON THE BACK OF THIS PAGE. WHEN YOU FINISH TURN IN YOUR WORK TO YOUR INSTRUCTOR.

13. Suppose a man needs to know how wide a swiftly flowing river is. He knows he can't cross the river and it is too wide to throw a rope over it. He sets up his experiment as follows. He spots a tree on the bank of the river opposite him and drives a stake into the ground on his side of the river directly opposite the tree. He measures along the bank a distance of 10 feet and drives another stake into the ground. Then he sites the tree from this stake and measures the angle formed by the line of site and the line to the other stake. He finds this angle measures 43° . How wide is the river?



Application Activity

14. There is a large cardboard semicircle with a plumb bob, a metric tape measure, a plastic protractor, and the table of trigonometric functions in the classroom.

a) How are changes in the line of sight related to the orientation of the semicircle and the plumb bob?

b) Adjust your semicircle/plumb-bob apparatus so that you may sight two different vertical objects on a distance wall and find the angle between the lines of sight of them.

15. Now use the apparatus to determine the height of the wall. If you want more detailed instructions, look on the next page. It is suggested, however, that you try to see if you can use the information you have learned so far without using those hints.

Let your instructor view your work before proceeding.

Detailed Instructions for obtaining height of an object using the plumb-bob.

1. Place a reference mark on the side of the object at your eye level. Measure the distance from the ground to this mark.
2. Measure away from the base of the object some convenient distance.
3. While standing the measured distance from the object, first sight to the reference mark you made in #1. Next sight to a point at the tip of the object vertically above the reference mark.
4. Determine the angle of sight and calculate the height of the object.
5. Add on the reference mark height above the floor and determine the total height.

**This learning cycle is a modification of an example given in a Workshop conducted by Robert Fuller, Director of the ADAPT project at the University of Nebraska--Lincoln.*

NAME _____

FORCES THAT MOVE OBJECTS

Exploration

In this exercise you will study forces necessary to move objects at rest from their stationary positions.

Be sure that you have the following:

- 3 rubber bands
- 1 meter stick
- 1 wooden block with a hook on one end
- assorted wafer weights
- 1 pan balance
- 1 inclined plane

The force necessary to move an object at rest should be applied by means of a rubber band and a meter stick. With the wooden block on the inclined plane in a horizontal position, in your own ingenious way devise a means of applying a measurable force to move the block. Be sure that you are able to measure the force each time it is applied.

Place the wooden block on a top-loading pan balance and determine its mass. (Be sure to "zero" the balance before you make a measurement with it.) Record this value in grams in the table provided.

With the rubber band, impress a force on a block until it moves. Measure a value for the force. Record the value in the table below. Record that value of the force that exists at the instant the block begins to move.

Put a 20-gram wafer weight on the block. Place this composite body on the plane. With the rubber band, impress a force on the body until it moves. Note and record the force applied. Add the 20-grams to the mass of the block and record this sum as the mass of the composite.

Repeat the procedure with 50-grams, 100-grams, 150-grams, 200-grams, and 300-grams on the block. Record your values of mass and force in the table.

Object	(Grams)	Applied Force

Invention

1. Are the applied forces the same in all cases, or are they different?
2. Why do you think they are the same (or different)?
3. What amount of stretch would be produced in the rubber band (as long as it did not break) if it were used to apply the force necessary to move from rest on the plane the block with 500-grams on it?

How did you arrive at your answer?

4. Plot a graph of force applied to move a body (on the y axis) as a function of mass (on the x axis). Draw a line "through" the points that best fits the data. What information does this line provide about the quantities being studied?

5. What would be the stretch in the rubber band if it were used to move a mass (block and weight) of 700-grams
6. If the rubber band were used to move a mass, and the band stretched 8-centimeters, how much mass was it moving?

Application

7. Look again at the data you collected (mass and force) when you used the block without a weight on it. Would the force be different if the block were resting on the table top?

Why?

Test your prediction by placing the block on the table top and measuring the amount of force necessary to move the block from rest.

Was the force different?

If it was different, in which case was the force greater?

Also, if it was different, what does this fact suggest concerning the block on the metal plane and the block on the table top?

Was (is) the table top clean or dirty?

Would "how clean the surfaces are" make a difference?

Explain.

8. If two (2) rubberbands, instead of one, were attached to the wooden block and used to perform all steps in the exercise, would the amount of stretch (considering the two rubber bands as one) be the same values that you observed in all steps?

Why?

Test your prediction with the unloaded block, the block loaded with 200-grams, and the block loaded with 300-grams.

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Object

(Grams)

Applied force

Was your prediction correct? Explain.

CAN PILLBUGS LIVE ON PHOTOMEDA?

In a not too distant galaxy is the planet Photomeda. The United States has the possibilities of putting a man on this planet by the end of this century providing the venture would be biologically feasible. In order to establish this principle the National Aeronautics and Space Administration (NASA) has given us a grant to see if pillbugs can live on Photomeda. NASA has sent us the following information.

Atmospheric Variable	Photomeda	Earth
Pressure	40-50 millibars (.6 lb/in. ²)	1013 millibars (15 lb/in. ²)
Temperature (average)	-62°C (-80°F)	(15°C (58°F))
Water vapor	Trace	Trace (maximum 2.5% at 23°C)
Carbon dioxide	90% of atmosphere	0.03% of atmosphere
Nitrogen (probably mixed with argon)	10% of atmosphere	78% of atmosphere
Oxygen	Negligible	21% of atmosphere

The table above compares some characteristics of the Earth's atmosphere with those of Photomeda. You are to duplicate some of these conditions in the laboratory to determine if pillbugs could live on Photomeda.

The low pressure of the Photomedean atmosphere can be duplicated by using a vacuum apparatus.

The high CO₂ atmosphere can be created by releasing an excess of CO₂ from the soda system.

The low temperature may be approximated by putting the flask in a freezer.

One way of proceeding is to duplicate all of the above conditions in one flask, and let that be our only experiment. Will this resolve all problems relating to the three variables we are studying? Why not?

You have probably theorized that each condition should be tested separately to see what the individual effects will be as well as together, to see what the synergistic results will be. The situation may be like drugs and alcohol. Taken separately they generally cause no harm but taken together they do. In other cases the synergistic effects could nullify the effects of each other.

Exploration

Our experimental Photomedian atmosphere will contain the following environmental factors.

1. Low temperature
2. High CO₂ level
3. Low pressure

Use the square below to arrange your variables so that you are sure that all possible combinations will be used. Use as many boxes as needed.

Flask 1 (control) CO ₂ , Temp., Pressure (normal Earth)	Flask 2	Flask 3	Flask 4
Flask 5	Flask 6	Flask 7	Flask 8
Flask 9	Flask 10	Flask 11	Flask 12

(All squares may not be needed). Check with your instructor before continuing.

Get ready to set up your flask as you have indicated in your boxes.

1. Add 4 pillbugs to each flask.
2. With a pair of forceps, put a disc of moistened filter paper in the bottom of each flask. This creates the water vapor environment in all flasks.
3. Create the environmental condition. (Your teacher will tell you how).
 - a. CO₂ will be placed in flask and stoppered.
 - b. Stoppered flasks that are to be subjected to cold will be placed in the freezer. A thermometer will also be placed there. When flasks are removed, wait 1 hour before observation.
 - c. Flasks simulating reduced atmospheric pressure will be vacuumed and stoppered.

Invention

A previous class has set up flasks that are identical to yours for your observation.

Data

Environment

Number of survivors

Write your conclusions in the space below.

Application

The gravitational pull on Photomeda is .2 that of earths. The Planet is also bombarded by gamma rays. Suppose you could simulate these conditions in a flask. Design an experiment to show what effects the Photomedian atmosphere (CO_2 , pressure, gravity, temperature and radiation) might have on pillbugs, using variables independently and all possible variations.

THE CASE OF THE MISSING LABELS:

AN ADVENTURE IN CHEMICAL IDENTIFICATION

Exploration

Last Friday after class those of us working in the general chemistry lab were preparing solutions for this week's experiment. We made four different solutions and labeled them AgNO_3 (silver nitrate), HCl (hydrochloric acid), HNO_3 (nitric acid), and NH_4OH (ammonium hydroxide). We poured portions of them into smaller bottles for use this week. We then suddenly noticed that it was time to quit and, in our haste to get started on the weekend, forgot to label the solutions in the small bottles. With the help of the party this weekend, we have forgotten which solution is in which bottle. You are now asked to help us determine which is which.

Your job is to perform whatever experiments you think are necessary to identify the unknown solutions, applying the best principles of detective work. You might begin by noting whether there are any obvious differences in the known solutions, such as color or odor differences. Then you might try mixing various combinations of the known solutions together to see what happens. When you apply the same procedures to the unknown solutions, you may see similarities in behavior which will help you figure out which unknown corresponds to which known. Get as much evidence as you can to aid in the identification.

The success of your work will depend on keeping a careful record of the observations you make and procedures you use. Use the following pages to keep your records.

Invention

A. Write down your conclusion about the identity of each of the three unknowns. State the specific evidence which led you to make the conclusion.

Solution 1:

Solution 2:

Solution 3:

B. Compare your identities with those obtained by the other members of the class. Are there any areas of disagreement? If so, what reasons led to these differences in identification?

C. Were there any solutions you could not identify with your procedure? If so, compare your method of identifying with that of other members of the class to see if there was some method which would have helped you to make better identifications.

Application

Now you're ready to move into the big time! In the lab you will find seven bottles which are labelled with the name of the substance in solution:

KClO ₃	KIO ₃
BaCl ₂	Na ₂ S
KI	Na ₂ SO ₄
AgNO ₃	

You will also find six bottles which are not identified except by number (4 through 9), but which correspond to six of the seven known solutions. Your job is to figure out the identity of each of the unknowns.

Remember to keep a very careful record of all observations and procedures. You can use the following pages for your records.

When you have completed all your tests, record below the identities of the nine solutions and the evidence that led to the identification.

Solution 4:

Solution 5:

Solution 6:

Solution 7:

Solution 8:

Solution 9:

COUNTING WITHOUT USING FINGERS OR TOES

Exploration:

Choose a partner or partners and take three squares of paper with a different letter on each square. One of you begin arranging and rearranging the letters in a line while one of you writes down the different arrangements. Record the different arrangements below.

Now choose a different letter from the box so that you have four different letters to work with. Working together as above, write down all the arrangements of these four letters.

1. How many arrangements of the letters did you find. Answer this by recording your results in the following table:

Number of letters	2	3	4	5
Number of arrangements				

2. How many arrangements are there of just two letters? Write your answer in the table above. Do your work below.

Invention

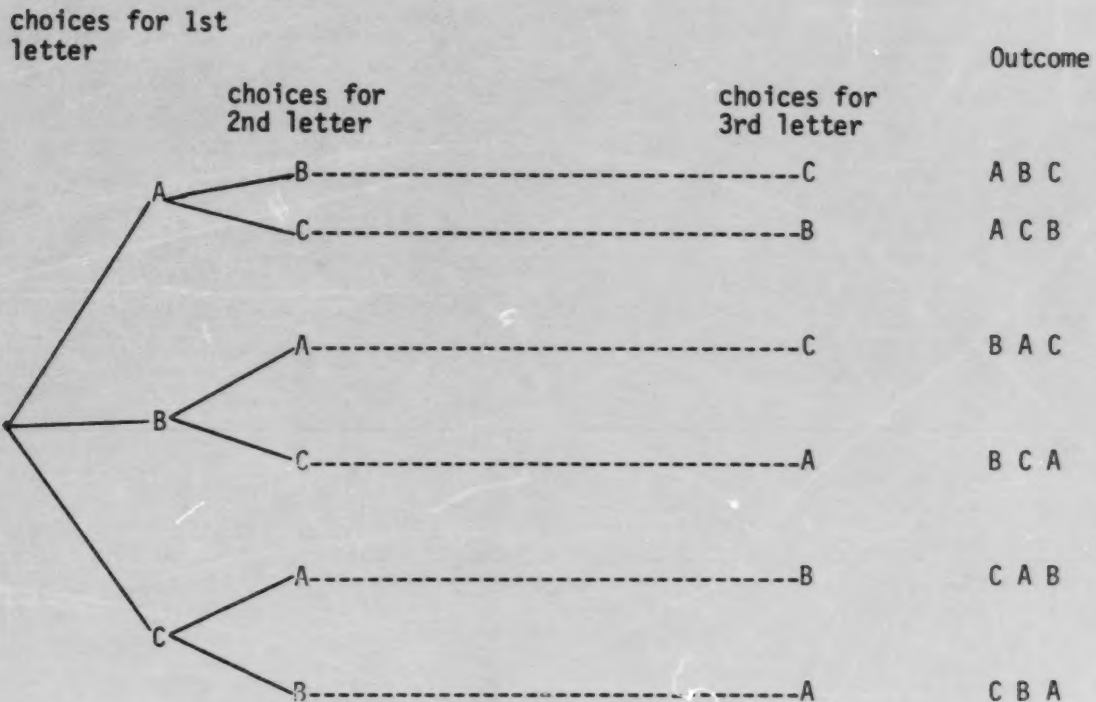
1. Describe below a systematic way one could write down all the arrangements of five letters.

2. How many arrangements of five letters would there be? Work this out below using your method in #1 and record your answer in the table on page 1.

Show your work to your instructor before you continue.

Tree Diagram

It is best to have a systematic way of writing down different arrangements of things like the letters in the first part of our lesson. One systematic way to go about making such a list is to make a tree-diagram. For example, if we want to rearrange in the letters in (A,B,C) we would have the following tree diagram:



The tree starts out with three branches to represent three choices for the first letter. For each choice of the first letter, there are two more choices left for the second letter; therefore, each of the original branches spread to produce two more. Finally, there is only one choice left for the third letter for each of the previous branches.

Application

Example 1: Draw a tree diagram to show the outcome of tossing a standard die and then flipping a coin.

Example 2: Draw a tree diagram to find how many ways four letters can be rearranged without repeating a letter. Summarize by stating the number of possible arrangements you obtain.

Show your work to your instructor before proceeding.

Invention

Sometimes it is not so important to give the list of arrangements of things as it is to know how many arrangements are possible. Let us review what we did in finding the outcomes of the experiment of tossing a die and flipping a coin.

There were two parts to the experiment. First, the number of dots that show on the die is recorded. Then heads or tails for the coin is recorded.

1. How many choices did we have at each stage of the experiment?
 - a) Number of choices at first stage = _____
 - b) Number of choices of second stage = _____
2. What is the sum of the two answers to #1?
3. What is the product of the two answers in #1?
4. How can we use the answers to #1 to find how many outcomes there were to the experiment of tossing a die and then flipping a coin.

Show your work to your instructor before proceeding.

Application

1. Write down in words the other parts to the experiment of arranging the letters A, B, C, and D.

1st pick the first letter to be used. _____

2nd pick the second letter to be used from the remaining letters. _____

3rd _____

4th _____

2. Tell how many ways each part can be done.

3. Show how the answers to #2 can be used to find how many ways four letters can be arranged.

4. How many arrangements can be made of seven letters?

Show your work to your instructor before you continue.

What you have just discovered for yourself is called the Fundamental Principle of Counting. It can be summarized as follows:

When an experiment consists of two or more parts, find the number of outcomes for each part and multiply them together. This product is the total number of outcomes for the experiment.

Work the problems below and show them to your instructor.

5. Radio stations in the United States have call letters that begin with either K or W (for west or east of the Mississippi River, respectively). Some have three call letters, such as WBZ in Boston, WLS in Chicago, and KGO in San Francisco. How many three-letter sets of call letters are possible?

6. Most stations that were licensed after 1927 have four call letters, starting with K or W, such as KFWB in Los Angeles, or KRLD in Dallas. How many four-letter sets of call letters are possible?

7. Helen bought a "mix and match" set of clothes to take with her on a trip. The set consists of three skirts, four blouses, and two vests. How many different outfits can she make?

8. In a certain state, license plates have one letter followed by four digits. How many license plates can the state make?

Show your work to your instructor before proceeding.

SUPPLEMENT TO COUNTING

Exploration

There are four pegs on the geo-board you have been given. Each peg has been labeled as either A, B, C, or D. Use the colored rubber bands you have been given to make triangles by encircling three pegs with a rubber band. For each different triangle use a different color rubber band. Record your data below.

Color #1	Color #2	Color #3	Color #4
_____	_____	_____	_____

letters used			

1. How many different triangles did you discover? _____
Show your work to your instructor.
2. How many four-sided figures could be made using these pegs?
3. Now draw the straight lines that the four pegs could determine using different colored pens. Remember "two points determine a straight line." Do your work on the diagram below.

A

B

C

D

4. How many different straight lines did you find? _____
5. List all the straight lines below. Name each straight line using the letters of the points which determine it.

Show your work to your instructor.

6. Record your data from page 8 below:

Number of points (pegs)	Number of straight lines	Number of triangles	Number of four-sided figures
		✓	

7. Now if we used three points only (for example A, B, C,) and repeated the experiment, what would be the results? Show them below:

Number of points	Number of straight lines	Number of triangles	Number four-sided figures

8. What if we used only two points (for example A and B) and repeated the experiment?

Number of points	Number of straight lines	Number of triangles	Number four-sided figures

Show your work to your instructor

Summarize your results so far in the table below:

9.

Number of points	straight lines	triangles	four-sided figures	five-sided figures	six-sided figures
2					
3					
4					
5					
6					

10. Explain how the data you have found so far can help you predict what should go in the rest of the blanks in the table.

Show your work to your instructor before continuing to the next page

Invention

11. Complete the following chart by adding the numbers at the beginning of the arrows and placing the sum in the blank at the end of the arrow.



12. Now use this method to fill in the next two lines above.

7 _____
 8 _____

13. What is the most number of straight lines that 5 points could determine?

14. How could check your answer experimentally? (Check the third page of this experiment.)

Show your work to your instructor before proceeding.

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A

B

C

E

D

70

Let us summarize what you have learned so far. We found that there were six straight lines determined by the four points A, B, C, D on page 10. By the Fundamental Principle of Counting we might be tempted to guess there would have been 12. Because we could have thought that there were 4 ways to choose the first point for the line and then only 3 ways to choose the second point $4 \times 3 = 12$. But there were only 6 lines to be found! The reason is that the F.P.C gives the number of arrangements of things. Straight line AB is the same as BA, so we don't want arrangements. We want combinations! A way of selecting things in which order is not important is called a combination. We can find how many combinations can be formed from a collection of things by using the chart on page 11. For example, the number of combinations of 6 things using only two at a time is 15. Now work the problems below and turn them in to your instructor.

Application: (Hint--Review the charts in questions 9 & 11 of the previous section.)

1. Herman has four friends he wants to invite on a boat cruise. But since his boat is small, he can invite only two friends. How many ways do you think he can choose the two friends he will invite?

Five coins are tossed. How many ways can we get each of the following? (problems 2-4)

2. Exactly two coins come up heads. (Find the number of combinations of 5 things (taken 2 at a time.)

3. Exactly three coins come up heads.

4. Exactly four coins come up tails.

5. In a club of eight members, how many different committees of three could be selected?

Show work to your instructor.

SWITCH COMBINATIONS

Exploration 1

This is an exercise in which your objective is to discover which switch, combination or combinations of switches in the "down" position will light a bulb or ring a bell when a button is pushed.

The materials needed are:

- 1 cardboard box with marked holes
- 5 switches
- 1 black button or key
- 1 power supply
- 1 light bulb or bell
- wire leads

The switches are identified by different colors, so that there are a "red switch," a "green switch," a "black switch," a "yellow switch," and a "white switch." Note on the cardboard box adjacent to the holes in which the switches are positioned the identification of the switches with the letters R, G, B, Y, and W--the letters corresponding to the first letters of names of the colors. The switches can be flipped in an "up" position or a "down" position. If the correct switch or combination of switches is flipped into the "down" position and the black button is pressed, the blub will light or the bell will ring.

In the space below and on the next page, write the labels (using the above-mentioned identifying letters) for the individual switches and as many combinations as you can form.

LABELS TABLE #1

How many labels did you write?

How many labels did your partner write? Use all of them in this experiment-- your and your partner's, if he/she has some that you did not think of.

Now determine which switch or combinations of switches in the down position will cause the bulb to light when the button is pressed. Try all of the combinations that you listed. Place a check (✓) mark beside the label of the switch or combination(s) that result in the lighting of the bulb. When a particular switch or combination has been tested, be sure to return the switch to the up position before testing another combination.

Invention 1

Which switch or combination(s) turned on the light bulb?

Suppose two of your switches in combination (maybe the black and white switches) resulted in the lighting of the bulb, do you suppose that the bulb will always light, regardless to which of the two switches is placed in the down position first?

Check your guess. With the first combination that turned on the bulb, find out if the lighting of the bulb depended on which switch was placed down first.

With each of the other combinations that turned on the bulb, determine if the order in which they are placed down makes a difference.

Can you make a general statement about the order in which switches in these combinations are placed down and the lighting of the bulb?

Exploration 2

You will now investigate why some switches or combinations turned on the light bulb and others did not.

Remove the the cardboard box by lifting it straight up. Note that each of the switches has wire leads connected to it.

Select the first combination of switches that turned on the light bulb. Place these switches in the down position. Starting at the second switch you placed down, trace the path from it through the next thing (either the first switch, or the button, or light bulb) to which it is connected, through the next, and so on, until you have returned to the switch at which you started.

Can you describe the path of connections?

Return all switches to the "up" position.

Repeat the tracing of the paths for each of the other combinations of switches that turned on the light bulb. Record a brief description of each path.

What do all of these tracings or paths have in common?

Now select a combination of switches that did not turn on the bulb. Place the two switches in the down position. Starting at the first switch that you placed down, trace the path from it to each of the other things to which it is successively connected. (If you arrive at a place where a wire is not connected to something, consider the path ended.)

Can you describe the path?

Repeat the tracing of the path for each of the other combinations that did not turn on the light. Record a brief description of each path.

What do all paths have in common?

Invention 2

How do these paths compare with those of combinations that turned on the lights?

Application

EACH GROUP OF STUDENTS NOW ROTATES (clockwise) such that you will work at the next desk with a different set of switches on it.

In the space below, using the letters R, Y, G, B, and W as switch labels, form as many different combinations as you can.

LABELS TABLE #2

How many combinations did you form?

Consult with your partner and make sure that each of you has as many as the other.

Determine if the light bulb will be turned on when each of these combinations of switches is in the down position, and the button is pressed. In a convenient style of your own, record the results in the appropriate cell of the table.

Which combinations resulted in the lighting of the bulb?

Using all of the information that you have collected and gained in this exercise, predict the path of connections (part of which is hidden by the cardboard box) for the first combination that turned on the bulb. Use the space below to diagram the path.

Predict the path for the first of your combinations which did not turn on the light bulb. Draw a diagram of it in the space below.

Check each of your predictions by removing the cardboard box as before and actually tracing the paths (individually) of the two combinations whose paths you diagramed.

Were your predictions correct? If they were different, tell how they were different from the actual paths.

ROTATE AGAIN clockwise to the next work table. For the switch apparatus there, write in the space below the combinations of switches that are possible.

LABELS TABLE #3

For each of the combinations you formed, find out if the light bulb will be turned on when the switches are in the down position and the button is pressed. Conveniently, record your results in the appropriate cells of Labels Table #3.

Choose one of the combinations that turned on the light bulb, and, with a diagram in the space below, predict the path of connections for it.

Select one of the combinations that did not turn on the bulb, and, with a diagram in the space below, predict the path of connections for it.

What GENERAL STATEMENT can you make concerning the paths of combinations that resulted in the turning on of the bulb?

What GENERAL STATEMENT can you make concerning the paths of the combinations that did not result in the turning on of the light bulb?

TONGUE ROLLING AND PROBABILITY

The probability of having a given type of offspring regardless of whether you are a) an expectant mother, b) a nurseryman, or c) a cattle breeder depends upon:

- (1) the genes that both parents possess
- (2) the genes that may be present in the gametes of each parent
- (2) the gene combinations that may result when the gametes combine to produce the new offspring

Notice that the term "may" has been because it is not certain or definite as to which genes will appear in a particular gamete or in a particular offspring. It all happens by chance.

Exploration (work in pairs)

You will be given knives, forks and spoons to be used as chromosomes. These "chromosomes" are to be placed on outlines representing a cell undergoing the meiotic or gamete production process. Your instructor will take you through the steps.

At the end of the process, your instructor will declare you as male or female and will have you to repeat the meiosis simulation, however, this time she will give you a pair of genes to be placed on a particular set of chromosomes. The two genes will determine the "tongue-rolling" characteristic, (One will be for tongue rolling, the other will not). Your instructor will have you define such terms as genotype, phenotype, dominant, recessive, homozygous and heterozygous.

At the end of the meiotic process, you will have "sperm" if you are the male and "eggs" if you are the female. Observe your gametes.

How many kinds of "sperm" do you have? _____

How many kinds of "eggs" do you have? _____

Invention

Take your "sperm" and fertilize the eggs of the female. Try all possible combinations so that you will see all of the possible kinds of offspring that you may get. Record this information in the following chart.

Eggs →

sperm ↓	offspring	offspring	offspring	offspring
	offspring	offspring	offspring	offspring
	offspring	offspring	offspring	offspring
	offspring	offspring	offspring	offspring

The offspring resulting from the union of a male gamete and a female gamete will inherit ____ genes for each characteristic. In this example the offspring could inherit one, two or no genes for tongue rolling.

Both gametes may contribute a tongue rolling gene to the offspring, or only one of the gametes passes along a tongue rolling gene. In another example, neither gamete contributes a tongue rolling gene.

In each pregnancy what is the probability of each child being a tongue roller? A nontongue roller?

The gene for brown eyes is dominant to that for blue eyes. Let the white bead represent the gene for brown eyes and the blue bead represent the gene for blue eyes. You are an individual who is heterozygous for brown eyes. Represent this on your fork chromosomes. What kinds of gametes (in terms of genetic materials) can you produce?

If you married an individual with the same genotype as yours, what kind of offspring could the two of you produce? (Indicate probabilities in your answer.)

Application

1. In humans, the gene for six fingers is dominant to the gene for five fingers. If both parents are heterozygous for six fingers, what is the probability of them having a six-fingered child? A five-fingered child?
2. What is the probability of a couple having a six-fingered child if the man is heterozygous for six fingers and the woman is five-fingered?
3. What is the probability of a couple having a tongue-rolling, six-fingered child if both are heterozygous for tongue rolling and six fingers? (The product rule of probability theory states that the frequency with which two or more independent events occur together is equal to the product of the frequencies with which each event occurs individually.)
4. If a man is heterozygous for six fingers and brown eyes and a woman is heterozygous for six fingers and blue eyes, what is the probability that they will produce a child with six-fingers and blue eyes?
5. If a man is a non-tongue roller, is five-fingered, and is heterozygous for brown eyes while his wife is heterozygous for tongue rolling, homozygous for six fingers and heterozygous for brown eyes, what is the probability of them having
 - a) a tongue-rolling, six-fingered, brown-eyed child?

b) a non-tongue rolling, five-fingered, blue-eyed child?

c) a non-tongue rolling, five-fingered, brown-eyed child?

6. Obtain some corn seeds from your instructor. Plant them as directed in class. Return periodically to observe and water them. You will need the corn sprouts for an analysis at a later date.

SIMULATED ISOTOPE DILUTION

OR

The Lazy Man's Way of Counting the Number of Jelly Beans in the Jar

Exploration I

You will be assigned to a group by your instructor. As soon as your group is formed, you should begin attempting to determine the number of beads in the container for your group without directly counting the beads. You will find balances, graduated cylinders, rulers, a container of yellow beads, empty containers, etc. in the laboratory. Use any or all or none of the equipment as you see fit. Describe below anything you do. You have 15 minutes to complete this activity.

Were you able to solve the problem? How many beads do you think are in the container?

List any evidence you have to indicate why you gave the above estimate. (If you don't have any evidence, it's O.K. to guess as long as you state that that's what you did.)

Exploration II

One of the techniques you can use to solve the type of problem on the previous page is similar to the "isotope dilution" technique sometimes used by chemists to determine the quantity of one particular substance when direct measurement of the total quantity is not possible. For example, if one wanted to know how much water is present in the human body, it would be most impractical, to say the least, to drain it and weigh it (or, worse yet, to count the number of water molecules).

However, if a small quantity of some radioactively "tagged" water is injected into the body and allowed to mix thoroughly with the water already there, the total quantity of water present can be determined. One must first measure the quantity of "tagged" water and its radioactivity level (determined with a Geiger counter) before it mixes. The factor by which the radioactivity level goes down (the dilution factor) after mixing with the body water allows one to calculate the quantity of body water present.

Let's try to determine the number of beads in the container by using a dilution technique with yellow beads as our "tagged" or "tracer" beads. We could really use any kind of object as a tracer, as long as we could distinguish it in some way from the beads we are working with.

1. Take a sample of yellow beads (perhaps 50 or so, as long as you know the exact number you are using.) Record the number below:

_____ Initial sample of yellow beads.

Now mix them thoroughly into the other beads. Get as even a distribution as you can.

2. Now remove a sample of mixed beads from the container by dipping a small beaker into the mixture and filling it. Determine the following:

_____ Number of yellow beads in sample

_____ Number of other beads in sample

Invention

1. How could you use the data you obtained on the previous page to determine the total number of beads initially in the container?

(If you do not see any way to use the data, discuss the problem with your classmates and your instructor.)

2. Calculate the total number of beads initially in the container.

_____ Number of beads

3. Put your sample of beads back into the original container, mix well, and take out another sample. Repeat the counting procedure for the number of yellow beads and other beads. Again calculate the total number of beads originally present.

_____ Number of yellow beads in sample

_____ Number of other beads in sample

_____ Total number of beads initially in container

4. Now list the results calculated by the other groups in the lab.

5. The containers were prepared with exactly the same number of beads in each. Did all groups arrive at the same estimate? Did you arrive at the same estimate when you did two determinations for your own container? If not, list some possible reasons here:

6. If you have to bet \$10 on the number of beads in the container, with the closest estimate winning, what number would you bet on? Why?

7. Now that you've spent all this time estimating, do an actual count of the beads in your container. You and your partner can divide the work.

Total count: _____ beads

8. All containers were prepared with an identical number of beads. List the estimated numbers you had from the dilution technique and from page 1 of the experiment (for all groups).

From dilution

From page 1

How well do the estimated numbers agree with the count?

Do all of the direct counts agree?

9. Now that you have numbers from several different methods, which number would you trust the most and why?

10. Would you bet \$100 that the number of beads cited in (9) above is the exact number of beads in the container? Why or why not?

Application

Remove the yellow beads from your container. Then take your mixture to your instructor and ask that it be altered into an "unknown." Now determine the number of red beads present in the container without counting all of them. Record your procedure and calculations on the following page.

87

96/97

TAKE YOUR CHANCES

Exploration

1. You will be given a green die which is very special. Someone has drilled out each spot on the six-dot side and inserted a #5 lead finishing sinker. We need to know how many times that this die will come up either one, two, three, four, five or six. Working in your group with each person taking turns to toss the die equally as often, toss the die a total of one hundred times and record your data below.

Number of dots on the side	tally	frequency	fraction = decimal
one			/100 =
two			/100 =
three			/100 =
four			/100 =
five			/100 =
six			/100 =

2. Now compare your results with the results of an other group. Find a grand total and a new fraction and record this below.

Number of dots on the side	sub-total of frequencies for 2 groups	fraction = decimal
one		/200 =
two		/200 =
three		/200 =
four		/200 =
five		/200 =
six		/200 =

3. After you have finished, show your work to your instructor. We will then write all the groups data on the blackboard. Combine all the data into the table below.

Number of dots on the sides	grand total	fraction	decimal
one			
two			
three			
four			
five			
six			

4. Your teacher will now give you the data he has collected for 1000 tosses of the die. Compare them with your group's data after copying your instructor's results below.

Number of dots on the side	grand total	fraction =	decimal
one		/1000 =	
two		/1000 =	
three		/1000 =	
four		/1000 =	
five		/1000 =	
six		/1000 =	

5. How does the data in #3 compare to that in #4?

6. Do you think that a two-dot side should come up more often or less often or about the same as a three-dot side? _____
As a four-dot side? _____
As a five-dot side? _____

Show your work to your instructor before you continue.

Invention

1. Using your data from question #4 on the previous page, predict the theoretical probabilities of the loaded die to be each of the following.

<u>Number of dots on a side</u>	<u>Theoretical Probability</u>
one	
two	
three	
four	
five	
six	

2. Predict how many times that a five-dot side will turn up if the loaded die is rolled 500 times.

3. Explain how you can use your answer in #1 above to answer question #2.

4. If someone rolled the loaded die 100 times and a five-dot side turned up only 10 times, would this mean your answer to #2 is wrong? Explain your answer.

Application

1. What is the probability that a five-dot side will turn up in a roll of the loaded die?
2. Write down a formula in words for obtaining probabilities.
3. What is the biggest number a probability can be? Explain.
4. What is the smallest number a probability can be? Explain.

Show your work to your instructor.

Probability was originally developed by two French mathematicians, Pierre de Fermat (1601-1665) and Blaise Pascal (1623-1662), while studying the theory behind gambling. Their results are now used to measure the likelihood of an event in games of chance or in any other area of prediction.

Probability is used by pollsters, for example, who can make remarkably accurate predictions of election results. Weather forecasters give the chances for rain in terms of percents. Business people use probability in a field called decision theory to help decide on the best products to market and the best ways to sell them. Biologists use probability to study genetics, the science of inheritance. Insurance companies employ people called actuaries to estimate the probabilities of life, accident, and health insurance claims.

We will see several examples of probability in this lesson.

Probabilities must sometimes be found by actual experiments. Such probabilities are called experimental probabilities.

If a paper cup is tossed and allowed to land on a level surface, there are three possible outcome: landing on its side, landing on its top, and landing on its bottom. The only way of finding the probability of any of these outcomes is by repeatedly tossing the cup.

The table below shows the tallied results of 30 actual tosses. By counting the tally marks for a given outcome, we can find the number of times that the outcome occurred. We call this number the frequency of an outcome.

1. Complete this table.

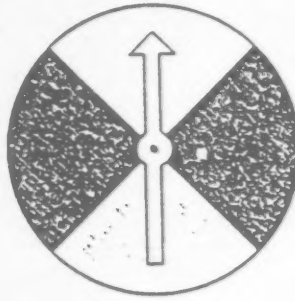
outcome	Tally	Frequency	Probability
Top			
Bottom			
Side			

2. Which outcome has the greatest experimental probability?
3. Write down a formula for finding experimental probability in words.

4. Explain in words how your formula in #3 shows that the biggest number a probability can be is "1" and the smallest number a probability can be is "0."
(Hint: Recall your formula for probability in questions #3 above.)

Show your work to your instructor.

Sometimes probabilities can be found by making certain assumptions about a given situation. For example, the circle shown here is divided into four equal regions. Assume that when we spin the pointer, we always land within one of the four regions, and never on a border line. We say then that any spin has a total of four equally likely outcomes.



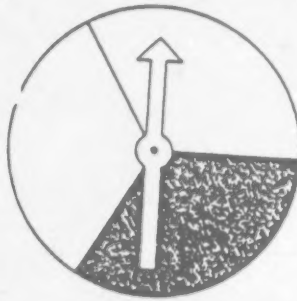
4. If we spin the pointer 8 times, we would land on black about how many times?
5. If we spin the pointer 10 times, about how many times would it land on black?
6. Write down a formula in words to show how you got the answers to 4 and 5.

Show your work to your instructor.

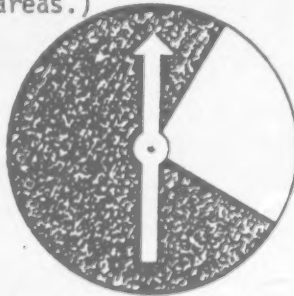
Application

Give the probability of each event in the following exercises.

1. If you spin the pointer shown here, it lands on black.



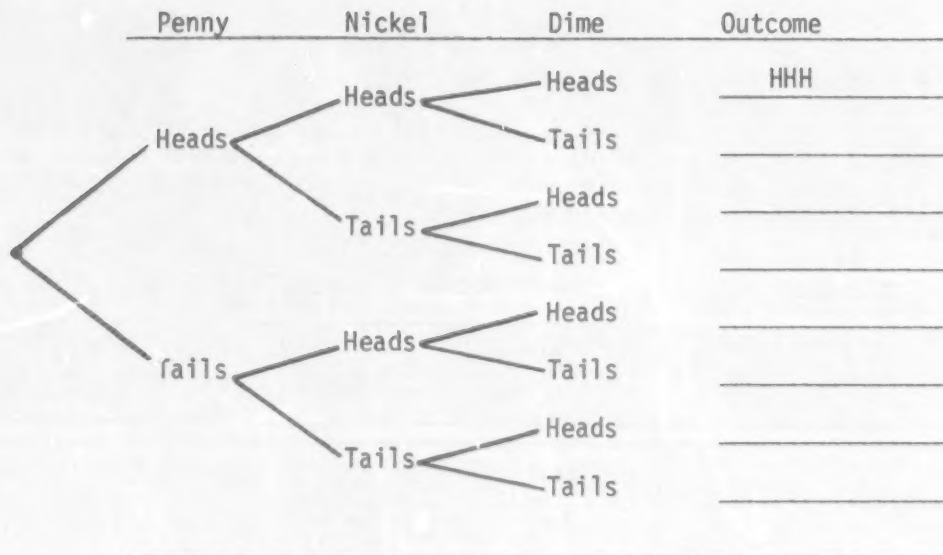
2. If you spin the pointer shown here, it lands on white. (Assume each circle is divided into 4 equal areas.)



3. If you roll an ordinary die, it turns up 4. (An ordinary die is a cube with six faces--the first face has one dot, the second face has two dots, and so on.)
4. If you roll an ordinary die, it turns up an even number.
5. If you roll an ordinary die, it turns up a number greater than 4.

Suppose Susan has a drawer in her dresser which has 2 blue sweaters, one red sweater, and three blue shirts. Answer the following questions using this information.

6. What is the probability of drawing a sweater from the drawer?
7. What is the probability of drawing on one try a blue item from the drawer?



8. Complete the list of outcomes in the tree diagram above. Using this tree diagram, complete the following table.

	Number of heads	Frequency	Probability
9.	3		
10.	2		
11.	1		
12.	0		

13. Use the tree diagram to find the probability of getting three heads.

14. Use the tree diagram to find the probability of getting at least one head.

Show your work to your instructor.

SUPPLEMENT TO TAKE YOUR CHANCES

Exploration

1. Draw a tree diagram to help you systematically list all the outcomes of picking a shirt and a sweater from a drawer conaining 3 shirts (A, B, C) and 4 sweaters (s,y,z,w). Only one sweater and one shirt will be used at a time--ex, Shirt A, sweater s.

Show your work to your instructor.

2. Draw a tree diagram to help you list all the outcomes of rolling two dice (pretend we will look at the red die first)

Each of the 36 outcomes can be expressed as an ordered pair of numbers. List the outcomes of the red die first and the green die second. We can then assign a dot sum to each ordered pair. This is the sum of both outcome--a total of all the dots. Notice that the ordered pairs (1,2) and (2,1) both have a dot sum of 3, even though each represents a different outcome.

2. Fill in the missing ordered pairs and dot sums in the figure below.

Dot sum	Ordered Pairs	Frequency	Probability
2	_____	_____	_____
3	_____	_____	_____
4	_____	_____	_____
5	_____	_____	_____
6	_____	_____	_____
7	_____	_____	_____
8	_____	_____	_____
9	_____	_____	_____
10	_____	_____	_____
11	_____	_____	_____
12	_____	_____	_____

3. Is there any way of getting a sum of 2 besides (1,1)?

4. What is the probability of rolling "snake eyes", that is, a sum of 2?

* Recall that the probability of rolling a 1 when one die is rolled is $1/6$.

5. Show how this fact can be used to find the probability of (1,1) when two dice are rolled.

6. What is the probability of a 2 when only one die is rolled? _____

Show your work to your instructor.

7. Show how your answer is #6 and (*) can be used to find the probability of a (1,2).
8. What is the probability of (2,1)?
9. List the ways of a dot sum of 3 can be obtained.
10. Show how your answers to #7 and #8 can be used to find the probability of getting a dot-sum of 3.
11. List the ways of getting a dot sum of 5.
12. What is the probability of a dot sum of 5?

Show your work to your instructor.

Invention

In general, when the probability of two events occurring together is needed and when the first event does not have an effect on the other event, we may just multiply the probabilities of the individual events to get the probability of both events occurring. For example, the probability of getting a "one" when a standard die is rolled is $1/6$. Thus the probability of "snake eyes" or (1,1) is $1/6 \times 1/6 = 1/36$. Thus, each pair of numbers which forms the list of outcomes for the roll of 2 dice has a probability of $1/36$.

Also, we can find the probability of dot sums by adding the probabilities of each of the outcomes which yield the desired dot-sum. For example, the dot-sum of 3 can be obtained by rolling (1,2) or (2,1). Thus the probability of a dot-sum of 3 is $1/36 + 1/36 = 2/36 = 1/18$. This still will be true even if the probabilities of each outcome are unequal.

Application

Recall from our first experiment with the loaded die that we found the probabilities for the roll of a single loaded die to be approximately as follows:

number of dots on side	Probability
1	.21
2	.17
3	.17
4	.17
5	.17
6	.11

1. Fill in the following chart to find the probabilities of each pair of numbers in the outcomes of a roll of two loaded dice.

(over)

Green	Face	1	2	3	4	5	6
Face	Prob.	.21	.17	.17	.17	.17	.11
1	.21	.0441					
2	.17						
3	.17						
4	.17						
5	.17						
6	.11						

Each of the 36 outcomes for the loaded dice can also be expressed as an ordered pair of numbers. List the outcome of the red die first and the green die second. We can then assign a dot sum to each ordered pair. This is the sum of both outcomes--a total of all the dots. Remember that the ordered pairs (1,2) and (2,1) both have a dot sum of 3, even though each represents a different outcome.

2. Fill in the missing ordered pairs and dot sums in the figure below.

Dot sum	Pairs	Total Probability
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

3. Compare the chart above with the one on page 11 for the fair dice. Explain why a cheater would want to slip his opponent the loaded dice when playing "craps".

Show your work to your instructor.

DICE-ATOMS RADIOACTIVITY ANALOG

Introduction

A. Radioactivity

Introductory remarks on radioactivity will be made by the instructor.

B. Dice-Atoms

The throwing dice provide an opportunity to utilize the probability of a particular face turning UP after the throw to create games of "chance".

Since the rate of radioactive decay depends on the "chance" of the disintegration of each single atom, an analog of radioactivity can be developed by substituting dice for the atoms and substituting the probability of a marked face turning up (after a die is thrown) for the probability of an atom disintegrating.

Dice of various shapes and colors can be used to represent different atoms in a radioactive series and the ratio of marked faces to total faces can be varied to provide different probabilities for a marked face to turn UP. Of course all the identical dice representing the same atom must have the same number of marked faces to insure the same probability of "disintegration" for each of the dice. It is convenient to use spheres to represent the final, stable, end products for there are no faces that can be marked, and turn UP, to indicate a disintegration.

The dice need not have numbered faces. If one face of each die is "marked" with a red dot, then after a throw any die found with a "marked" face UP is considered to have disintegrated.

The Analog apparatus consists of a storage tray with numbered nests for the dice, a throwing tray, a clear cover, the dice, spheres, and the red marker pen.

These fit together for convenient storage and the clear cover makes it possible to check that all the parts have been returned. 200 cuboctahedrons (14-faced, 8 triangular and 6 square) dice of a different color make up the daughter set, and 200 spheres make up the stable end produce set.

Whenever removing dice or spheres from the storage tray always take them from the lowest numbered nests first. Whenever returning dice to the storage tray always put them into the highest numbered nests. The highest uncovered number will always be the number of these particular dice or spheres in the throwing tray.

Exploration 1

Examine your set of dice-atoms and note that three kinds are present: 200 yellow cuboctahedrons (14 faced, 8 triangular, 6 square), 100 blue octahedrons (8 faced,) and 200 red spheres.

Let us examine the probability of a particular face of an octahedron turning up. One face of each octahedron is marked with a red dot. Place the 100 octahedrons in the Dice-Atoms apparatus. Tumble the number of red dotted faces that have turned up. Place that number in column 2 of Table 1. Calculate the probability of an octahedron to land with the marked face UP.

Repeat the tumbling of the octahedrons four (4) more times. Record the total red dots up. Record your values in the table on the next page.

Invention 1

Calculate the values of the probability of an octahedron to land with a marked face up, $p(8)$.

throw (tumble)	number of red dots up	total dice in tray	Probability, $p(8)$ of a marked face landing up
1		100	
2		100	
3		100	
4		100	
5		100	
Average			

Calculate your average value of $p(8)$.

Take two of the octahedrons out of the throwing tray. What is the probability of your rolling them, throwing them, and having each of them turning up a red-dotted face on a single throw? Check your prediction.

What is the probability of each of the 100 octahedrons turning up a red-dotted face on single throw of them?

Tumble the dice and calculate this probability $p(8)$. How does it compare with your average value in Table 1? How long do you suppose it would take you to tumble the dice and have all of the 100 octahedrons land with a red-dotted face turned up on a single throw?

Let us now determine the probability of a particular, marked face of a cuboctahedron turning up. Note that one of the square faces of each blue die is marked with a red dot, and that either two or four of the triangular faces are marked with a black dot. Place the 200 yellow dice in the throwing tray and tumble them. Bounce the tray onto the table before uncovering. Count the number of dice with a black-dotted face turned up and record this number in column two (2) of Table 2. Count the number of dice with a red -dotted face turned up and record this number in column three (3) of Table 2.

Repeat this procedure four more times, recording the number red-dotted faces turned up and the number of black-dotted faces turned up, in Table 2.

Table 2

Throw (tumble)	Number of black dots (on Δ faces) turned up	Number of red dots (on $\square$ faces) turned up	total dice in tray	Probability $p(\Delta)$, of a black-dotted face turned up	Probability, $p(\square)$, of a red -dotted face turned up
1			200		
2			200		
3			200		
4			200		
5			200		
Averages					

Now let us check our probabilities in the following manner. Multiply $p(\Delta)$ by 8 and $p(\)$ by 6. Add the two products and identify the sum as p . How does p compare to 1.00 ? (Find the percent error in p .)

How do you account for the percent error in your value of p ?

$$\text{percent error} = \frac{\text{accepted value} - \text{experimental value}}{\text{accepted value}} \times 100\% =$$

Exploration 2

Parent - Daughter (Stable)

Prepare a sheet of graph paper so that a plot can be made of the Number of Atoms versus the Number of Throws. Provide space for approximately 30 throws.

Plot 200 parent atoms and zero end product atoms for the "0th" throw.

Place all the cuboctahedrons in the throwing tray.

Cover the throwing tray and tumble very well. Then pick out all of the cuboctahedrons which have come to rest with marked face UP, return these to the storage tray and replace them in the throwing tray with an identical number of spheres.

Plot the number of cuboctahedrons and the number of spheres now in the throwing tray versus the "1st throw".

Repeat the tumbling and replacement of "disintegrated" cuboctahedrons for about 20 throws. Plot the number of cuboctahedrons and spheres in the throwing tray after each throw.

Then for the parent and end product data connect the respective sequences of plotted points by a sequence of short straight lines. Short straight lines are used between the successive plotted points to convey the fact that no additional data could have been obtained for the intervals between the integral number of throws. Smooth curves can be fitted to the plotted points for the parent (and for the daughter); these can be considered extrapolations to the result that would be obtained using many more than 200 parent atoms at the "0th throw".

Plotted data equivalent to more than 200 parent atoms at the start can be obtained by combining the data obtained by several groups of students. Then it will be easier to fit smooth curves to the plotted points for a better extrapolations.

Invention 2

Tell what the two lines of the graph indicate is happening.

From the decay graph of the parent species, note that the original number of the parent atoms is 200. How many throws (measured on the graph to the fraction of a throw) were required to reduce that number to 100?

How many throws (to the fraction of a throw) were required to reduce the number of parent atoms from 100 to 50?

How many throw (to the fraction of a throw) were required to reduce the number of parent atoms from 50 to 25?

Is there any relationship between the last three answers you gave?

If so, what is it?

From your graph, can you predice if and when the number of parent atoms is (or will be) reduced to zero? Explain.

Application

Parent - Daughter - End Product

Start with all the 8-faced dice and all the spheres in their storage tray nests.

The 200 cuboctahedrons are in the Dice-Atom Apparatus.

Prepare a sheet of graph paper so that (depending on faces marked on the dice) a plot similar to a corresponding graph in Figure (3) can be made for the Number of Atoms versus the Number of Throws. Figure (3) is provided by the instructor.

Plot 200 parent atoms, zero daughter atoms, and zero end produce atoms for the "0th throw".

Cover and tumble very well. Pick out all the octahedrons which have come to rest with a marked face UP, return these to the storage tray and replace in the throwing tray with an identical number of spheres. Then return the marked cuboctahedrons to the storage tray and replace in the throwing tray with an identical number of 8-faced dices.

Plot number of cuboctahedrons, 8-faced dice, and spheres in the throwing tray versus "2nd throw." Repeat the tumbling and replacement of "disintegrated" dice for about 20 throws.

Plot number of cuboctahedrons, 8-faced dice, and spheres in the throwing tray after each throw.

Then for the parent, daughter, and end produce data connect the three respective sequences of plotted points by short straight lines. Now see the last two paragraphs of the instructions for Exploartion II.

Select one of your cuboctahedrons and count the number of triangular faces with a dot. Now count the number of faces with a dot on one of your octahedrons. The instructor has a set of curves to which your experimental curves are to be compared. Obtain the set of curves from him/her that were plotted from data that were collected using the same number of dotted faces as you counted on your dice.

What likenesses among the two sets of curves do you see? Explain each fully.

From your experimental curves, determine the following:

- a) half-life of the parent species
- b) peak population value of the unstable daughter species
- c) time (in throws) when that peak value is attained
- d) rate at which stable daughter atoms are formed
- e) rate at which unstable daughter atoms are formed
- f) rate at which unstable daughter atoms decay
- g) half-life of the unstable daughter atoms

THE CASE OF THE MISSING FLAGELLA

Exploration

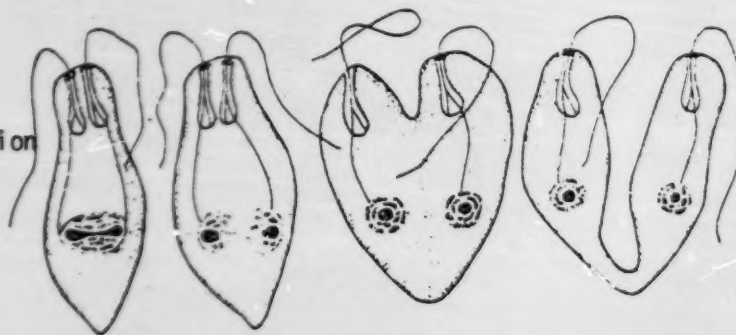
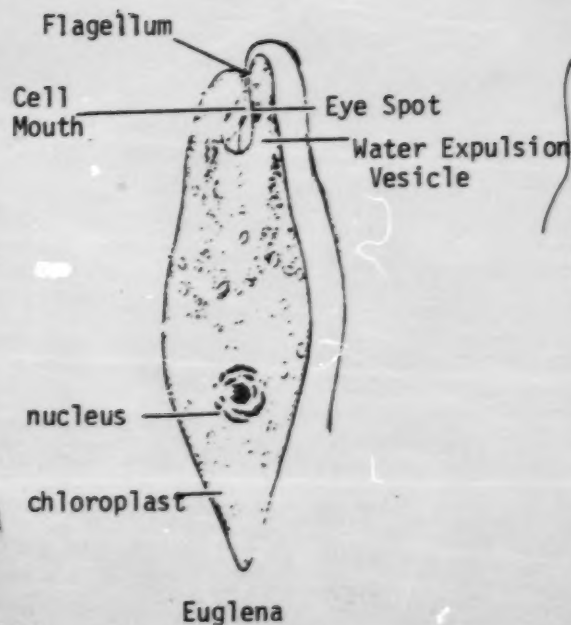
The students in the Monday section of the Zoology 114 Lab were studying the Protozoans and the organism for the day's observation was the Euglena. The Euglena culture had arrived two days ago from the Biological Supply House and had been divided and put in bottles I and II. Bottle I had been placed on the window sill by the 1st lab table to be used by students sitting at tables 1 and 2. Bottle II had been placed on the window sill by the 4th table to be used by students at table 3 and 4. A sterile pipette was placed at each culture.

Each student was to withdraw a sample of the culture, make a wet mount, observe the organisms under the microscope and make diagrams of (1) an individual Euglena (2) a Euglena undergoing fission.

Burt Einstein did not want to wait in the line that had formed to get samples of the culture so he picked up a pipette that was on the table and went directly to bottle I and got his sample. The pipette had been used in the Botany lab only minutes earlier while the botany students were testing the effects of Hormone A on some phase of plant physiology. The pipette was used to deliver the hormone.

The teacher reprimanded Burt and reiterated that only the sterile pipette is to be used.

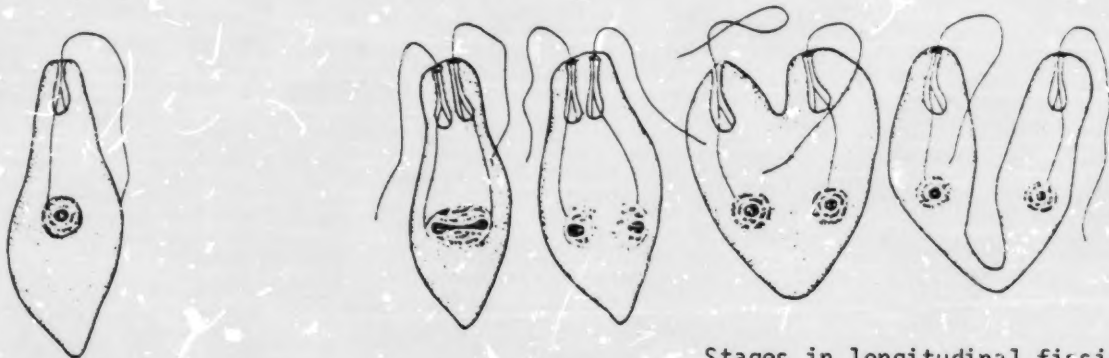
Lab drawings from that class looked like this .



Stages in longitudinal fission

The students in the Wednesday section of the 114 Lab had the same assignment. While making her observations Amile Carter said, "Some of my Euglenae don't have flagelia." Two other students made the same statement. The teacher observed the organisms in question and found them to be without reservoirs or flagella. The students had taken the sample from bottle F.

Lab drawings from that class looked like this.



Stages in longitudinal fission



Stages in longitudinal fission



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Do you notice any differences between the drawings for the two classes?
If so, what?

Today you will be studying the same two cultures to determine if there is any real difference between the two or if the drawings were just a mistake. You should remember that Bottle I has been contaminated by a pipette containing Hormone A whereas Bottle II has been in contact only with clean, sterile pipettes. In order to save time, one-half of the class will work with one culture and one-half with the other. Your instructor will indicate which you should investigate. After receiving a culture assignment, each of you should

- a) select a sample of ten organisms (sight unseen) from your assigned culture,
- b) record your observations in the following table,
- c) record your observations in the appropriate place on the chalkboard, and
- d) transfer other individual's observations into the table as they appear.

Sample No.	Single Euglena with Flagellum	Single Euglena without Flagellum	Euglena-fission with 2 Flagella	Euglena-Fission with 1 Flagellum
------------	----------------------------------	-------------------------------------	------------------------------------	-------------------------------------

Invention

Is there a relationship between flagellum-less Euglenae and the hormone?

What data suggest a relationship?

Return all samples to the cultures from which they were taken, shake the "cultures," and take another sampling. This time each of you should select 13 specimens if you are sampling Bottle I and 19 if you are sampling II. As before record the data both below and on the chalkboard.

Is there a relationship between flagellum-less Euglenae and the hormone?

What data supports your answer?

In order to interpret results and draw conclusions from data gathered in the laboratory, it is sometimes necessary to use statistical analysis. Statistics deal with the probability of an event happening. Chi-square (χ^2) is a statistical test or procedure in which observed results are compared with theoretical expectations to determine whether the observed deviation from predicted results are due to chance alone or some other factor. The χ^2 value is determined by using the following equation:

$$\chi^2 = \sum \frac{(\text{observed} - \text{expected})^2}{\text{expected}}$$

Chi-square is arbitrarily considered to be statistically significant when the probability is less than 5%.

Chi-square tells us if the probability is that our observed deviations are:

- a. too large/small
- b. may/may not be attributed to chance.

Using the data from your observations in the two previous tables, as well as information given to you by your instructor, calculate χ^2 to determine if flagellum non-production in Euglena is by chance or due to some other factor.

Application

On the back table are two cages of rats that were upstairs in the animal room. Note the "A" on one cage and the "B": on the other. One night about a month ago, the rats in cage A escaped from their cage (the lock was faulty) and knocked over a jar of pills that were on a shelf in the animal room. When Mrs. Wright came to work the following morning, she found the shattered jar on the floor but all of the pills were missing. She recovered all of the rats and secured them in another cage.

You are to observe the rats in both cages. How do they differ?

Take a sampling of both cages and tabulate your results.

Is there a relationship between fat rats and the pill? Support your answer using Chi-square.

Completion of Application from last week

Observe the corn seeds that were planted last week. The parents of these seedlings were both heterozygous for green leaves. Determine the expected phenotypic ratios for these seedlings.

Do your actual phenotypic ratios approximate the expected phenotypic ratios? Support your answer using chi-square.

SHAKING THE BLUES, CHEMISTRY-STYLE

Work in partners in this experiment.

Exploration

1. With your graduated cylinder, carefully measure 125 ml of 0.5M NaOH (sodium hydroxide) solution, and pour it into a 250 ml Erlenmeyer flask. Add EXACTLY 5 drops of methylene blue dye solution.

Obtain from your instructor four 1-gram samples of glucose. Add just one gram of the glucose to the flask with the NaOH and methylene blue. Swirl the flask gently to dissolve the glucose, then wait until the blue color disappears from the solution.

2. When the color is gone, cork the flask TIGHTLY. Shake the solution for EXACTLY 10 seconds. Then begin timing from the point when you stop shaking, and note the number of seconds it takes for the blue color to disappear. (You will notice that even when the blue color has faded from most of the solution, a layer of blue remains on the surface. Do not wait for the blue surface layer to disappear. As soon as the color is gone from the rest of the solution, stop your timing.)

Record the number of seconds required for the color to disappear. _____
(Do not include the 10 seconds during which you were shaking the flask when you record this time.)

Loosen the cork to allow air into the flask. Then tighten the cork again, and repeat the shaking procedure again. Record the number of seconds obtained in the second trial: _____

3. Now add one more gram of glucose to the flask. Swirl until it dissolves. The flask now contains a total of two grams of glucose. If any blue color is present, wait for it to disappear. Cork the flask, shake for 10 seconds, and start timing again. Record the number of seconds, and repeat the procedure a second time.

Go through the above procedure after adding another gram of glucose to give a total of three grams, and then the final gram to give a total of four. Each time you add glucose, do two time measurements. Summarize all of your data in table on the following page.

DO NOT THROW OUT YOUR FINAL SOLUTION. YOU WILL NEED IT FOR THE LAST PART OF THE EXPERIMENT.

Number of grams of glucose	ml of 0.50M NaOH used	Shaking time	Number of seconds for blue color to disappear			
			Trial 1	Trial 2	Averages: Your Group Others	
1	125	10 sec				
2	125	10 sec				
3	125	10 sec				
4	125	10 sec				

(Also write your data in the table on the blackboard so that the other groups can record it.)

4. In the above experiments you have been varying the amount of glucose used while holding constant the sodium hydroxide solution and shaking-time. To see whether or not the sodium hydroxide has any effect on the length of time the blue color persists, experiments were done in which glucose and shaking-time were held constant while the quantity of sodium hydroxide was varied. The results of these experiments were given below. (You do not have to repeat these experiments. We will assume that they were done carefully and that the results are valid.)

Number of grams of NaOH	ml of 0.25M glucose used	Shaking time	Number of seconds for blue color to disappear			
			Trial 1	Trial 2	Trial 3	Average
2	125	10 sec	290	320	325	312
3	125	10 sec	175	170	176	174
4	125	10 sec	90	115	110	105
6	125	10 sec	45	45	49	47
8	125	10 sec	30	30	32	31

Invention

1. Since everyone followed the same instructions and used the same solutions, why did everyone not obtain exactly the same number of seconds for persistence of the blue color with the four samples of glucose?

2. Taking into account all the data for each sample of glucose, can you tell whether there is a relationship between the quantity of glucose used and the length of time the blue color persists? If so, describe the relationship. If not, explain why you think there is none.

3. Plot the number of grams of glucose vs. the number of seconds the blue color persisted in solution. (Use the average number of seconds your group obtained as well as the average number of seconds the other groups obtained for each sample of glucose. This will give you a cluster of points for each glucose sample.)

What additional information does the graph give you about the relationship between quantity of glucose and color persistence?

4. Now look at the data from the experiments in which the NaOH was varied (p.2). Describe the relationship between the quantity of NaOH used and the length of time the blue color persists.

How is this relationship different from the one between glucose and length of time the color persisted?

5. Plot the number of grams of NaOH vs. the average number of seconds the blue color persisted.

Does the graph give additional information about the relationship between quantity of NaOH and color persistence?

Application

Using the solution you ended up with from the Exploration part of this experiment (4 grams glucose in 125 ml of 0.25M NaOH and 5 drops methylene blue), conduct experiments in which you vary the shaking-time while everything else is held constant. (Remember to loosen the cork after each trial, and then tighten it again before shaking.) Data can be recorded in the table below.

Number of grams of glucose	Ml of 0.25M NaOH used	Shaking time	Number of seconds for blue color to disappear		
			Trial 1	Trial 2	Average
4	125	5 sec			
4	125	10 sec			
4	125	15 sec			
4	125	20 sec			
4	125	30 sec			

Describe any relationship between shaking-time and the length of time the blue color persisted.

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Plot the shaking-time vs. number of seconds of color persistence. What does the plot suggest?

MAKING PREDICTIONS WITH GRAPHS

Exploration

The following data table gives the grades in freshman math corresponding to the intelligence test scores of a random sample of 10 freshmen at Xavier. Plot the data on the graph paper provided. Then answer the questions below.

Student	Test score, x	Math grade, y
1	63	87
2	50	74
3	55	76
4	65	90
5	55	85
6	64	92
7	70	98
8	58	82
9	68	91
10	52	77

1. What is the nature of the relationship between x and y?
The points follow closely what kind of graph?

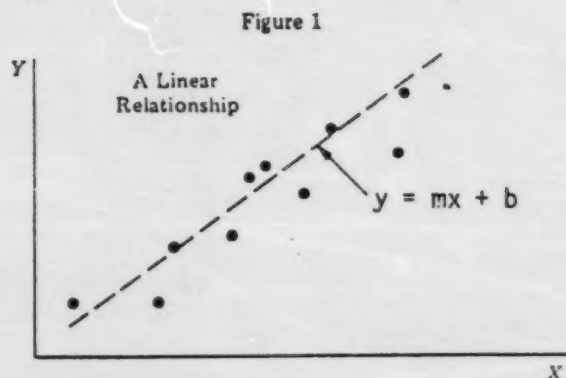
2. There is a tendency for small values of x to be associated with _____ values of y and large values of x to be associated with _____ values of y. (Hint: Study the chart above.)

3. How strong is this relationship? (That is, do the points "fit" the graph very closely, not so closely, etc.?)

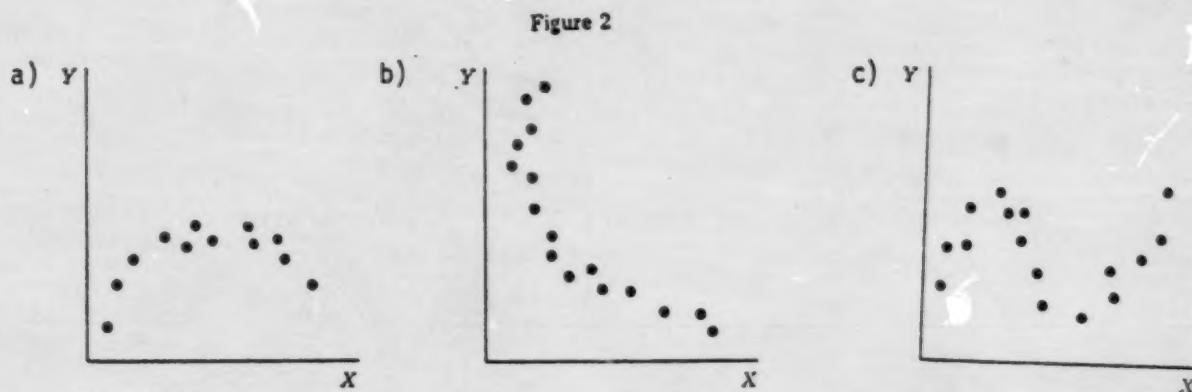
Show your work to your instructor.

Invention Types of Relationships

In answering the first question we will distinguish two basic types of relationships, linear and nonlinear. A linear (or straight-line) relationship is one which the overall pattern in the n points can be adequately approximated by a straight line (that is, a graph whose equation is of the form $y = mx + b$).



1. See if the following graphs seem to be best approximated by a line or a curve.



2. Question: What kind of relationship was exhibited in our original data? Use the graph you drew to help you answer.

Application

1. Now draw the "best" line for the original data and find the equation of this line. Do your work here.

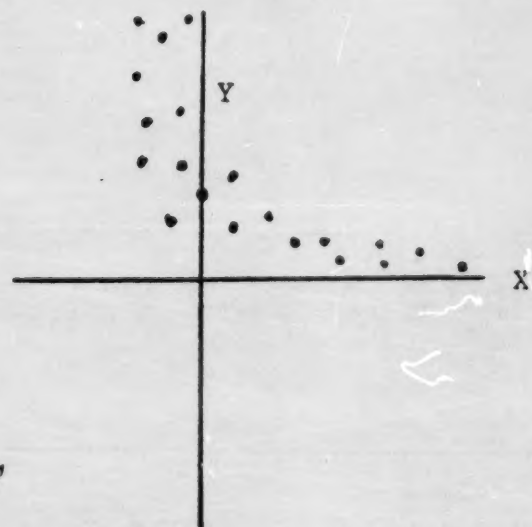
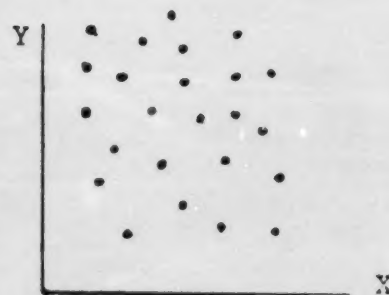
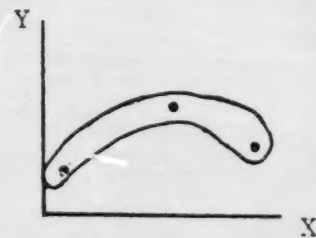
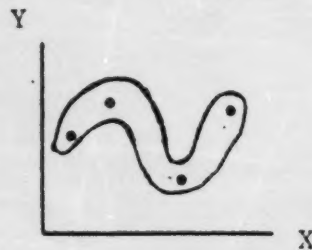
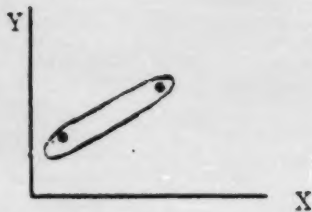
2. Use the equation you have found to find what a student with an intelligence score of 75 might expect in math class. Do your work here.

3. Does your answer mean that a student with an intelligence score is definitely going to make the score you predicted in #2? Explain.

Let your instructor inspect your work when finished.

Application (continued)

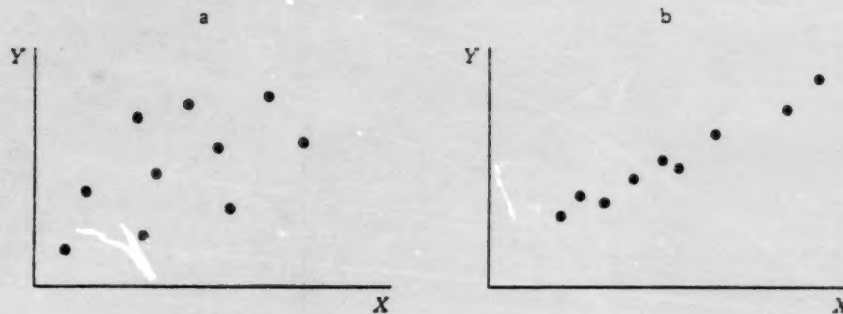
Look at the following graphs and tell whether the relationship expressed between x and y is linear or not. Graphs of the type below are called scattergrams.



Exploration

Knowing that a relationship is linear -- even knowing the exact equation of the line which best fits the data - does not tell us everything we need to know about X and Y . The two relationships graphed in Figure 3, for example are both linear, but very different.

Figure 3



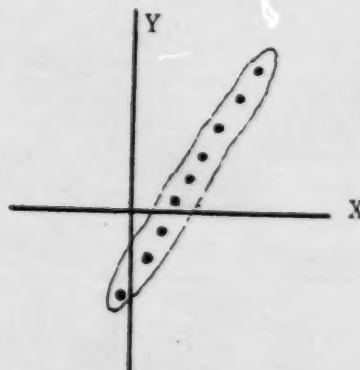
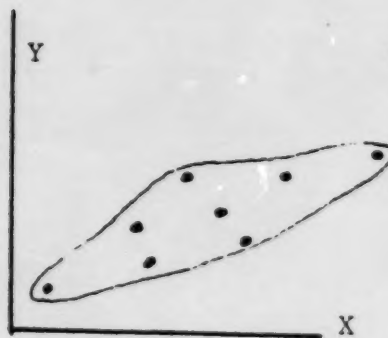
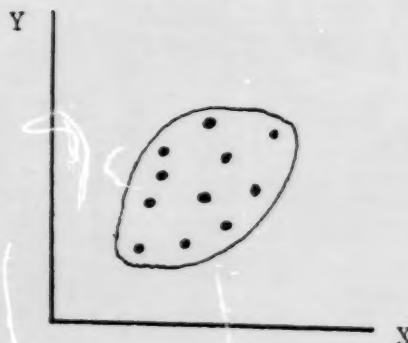
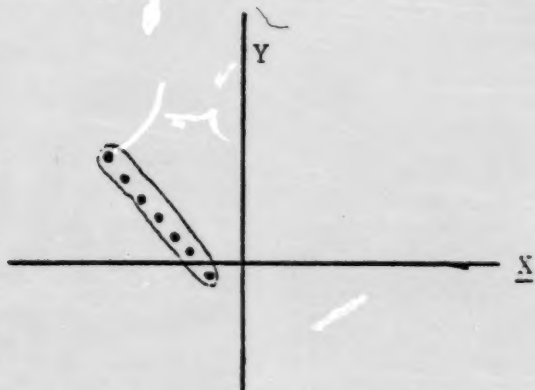
1. Explain the differences you see in the above scattergrams.
2. Which graphs on page 4 look more like 3b above?
3. Which graphs on page 4 look more like 3a above?

Show your work to your instructor.

Invention

The linearity is much stronger in Figure 3b than it is in Figure 3a. This raises an obvious question. Is there some way that the strength of a linear relationship can be quantified? If the answer is to be yes, we will need a way to measure the strength of the relationship. Before we go any further, let us agree to draw a lining around the scattergram to help us see the general shape that the majority of the dots determine.

1. Describe the differences you see between the "clouds" of dots in the figures below.



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Show your work to your instructor before continuing.

2. How can you measure these differences?

3. For each figure in problem #1 measure its width W and its length L and record your data in the chart below..

figure number	width W	length L	$W + L$	$L - W$	WL	W / L	RATING OF "SKINNINESS"*

4. Which figure is the skinniest?

Which is the fattest?

5. Which figure has the dots stretched out more closely to an (imaginary) line?

6. Which figure has the smallest W/L ratio?

7. Make a general statement about how "skinniness" of a cloud of dots could be measured.

*By looking at the graph, rate the graphs according to 1st skinniest, 2nd skinniest, etc.
Show your work to your instructor before continuing.

Summary I

The measure you have just discovered (namely $1 - \frac{W}{L}$) is called the correlation coefficient. Really the correlation coefficient has a very complicated mathematical formulation. Our formula only gives a rough estimate, but is useful. The correlation coefficient is usually denoted by r . We summarize the method of computing r as follows:

Step 1. Enclose the dots of the scattergram in a cloud.

Step 2. Measure the length L and the width W of the cloud.

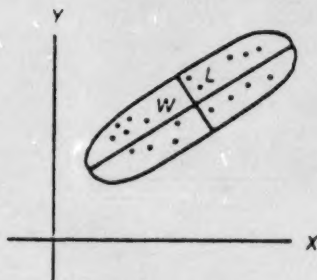
Step 3. Substitute the length L and the width W into the formula

$$r = \pm \left(1 - \frac{W}{L} \right).$$

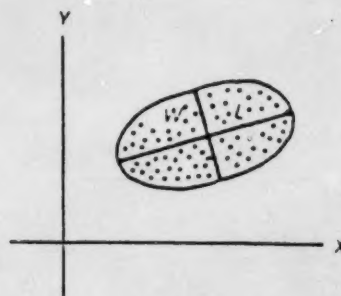
Step 4. The sign in the formula is to be chosen so that it agrees with the slope of L . That is, if the cloud seems to lean to the right the sign is $+$. If it leans to the left, the sign is $-$.

NOTE: Use any unit of measure you like, but it may be easiest to let the width W be one unit and estimate the length L as a multiple of W . For example, L might be $\frac{1}{2}W$ or $3W$, etc.

HERE ARE SOME EXAMPLES.

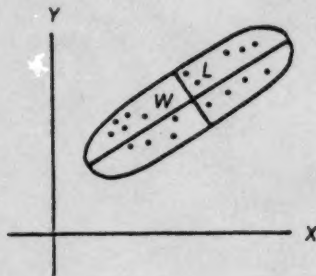


$$W = 1, L = 4, r = 1 - \frac{1}{4} = \frac{3}{4}$$

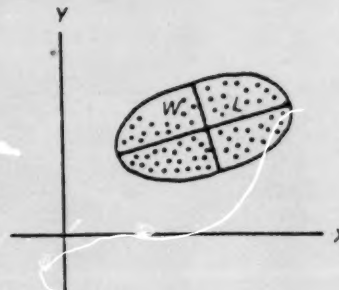


$$W = 1, L = 2, r = 1 - 1/2 = 1/2$$

See if you agree with the following two examples.



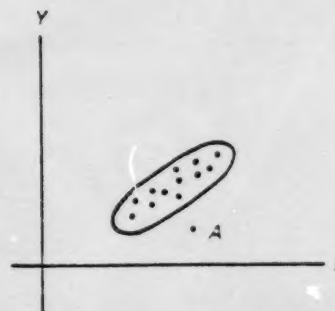
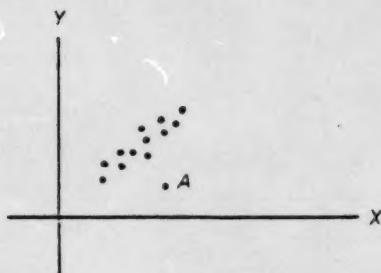
$$W = 1, L = 4, r = 1 - \frac{1}{4} = \frac{3}{4}$$



$$W = 1, L = 2, r = 1 - 1/2 = 1/2$$

If the points were fairly close together inside an elliptical cloud, this method would work pretty well. Unfortunately in practice, scores don't tend to behave nicely and isolated points make it hard to determine exactly how the lining should be draw in the figure below, inclusion of the point A would lower the estimate of r it's probably better to exclude it and then lower the estimate of r a little:

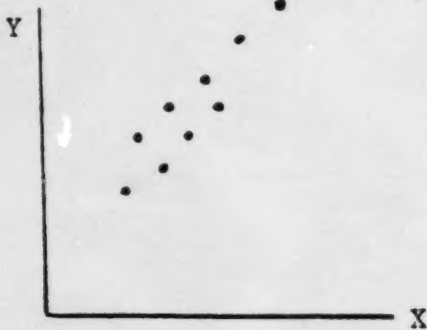
$$1 - \frac{W}{L} = 1 - \frac{1}{4} = \frac{3}{4} = .75 \quad \text{We use } r = .7$$



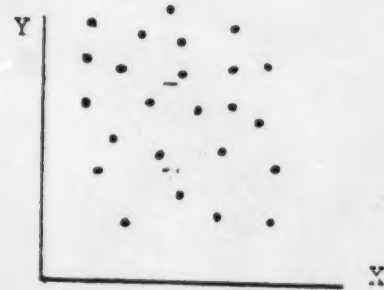
Application

Use the method described on pages 9 and 10 to calculate r for each graph below.

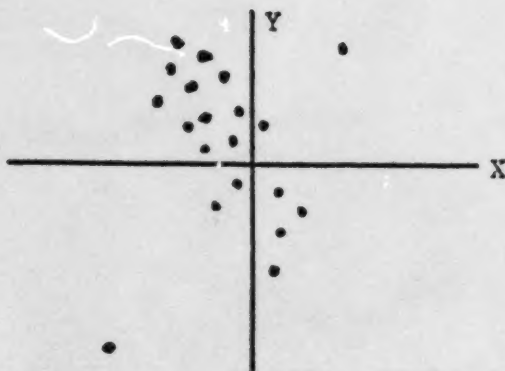
1.



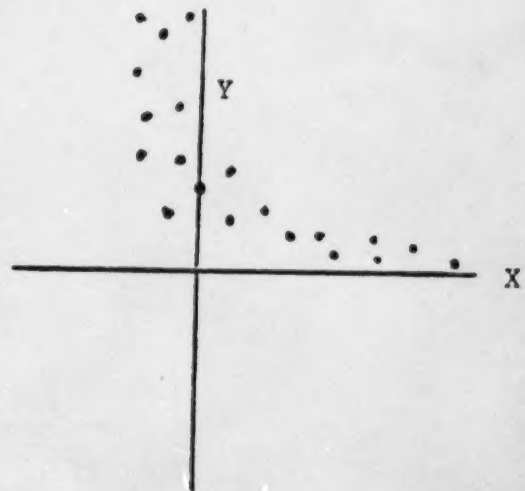
2.



3.



4.



Show your work to your instructor

Summary

Values of r close to -1 indicate a strong negative correlation (large values of Y are associated with small values of x and large values of x are associated with small values of y).

Values of r close to 0 indicate that there is essentially no linear relationship X and Y .

It is important to remember that the correlation coefficient between two variables is a measure of their linear relationship, and a value of $r = 0$ implies a lack of linearity and not a lack of association. Hence; if a strong quadratic relationship exists between x and y as indicated in Figure 4(d), we shall still obtain a zero correlation to indicate a nonlinear relationship.

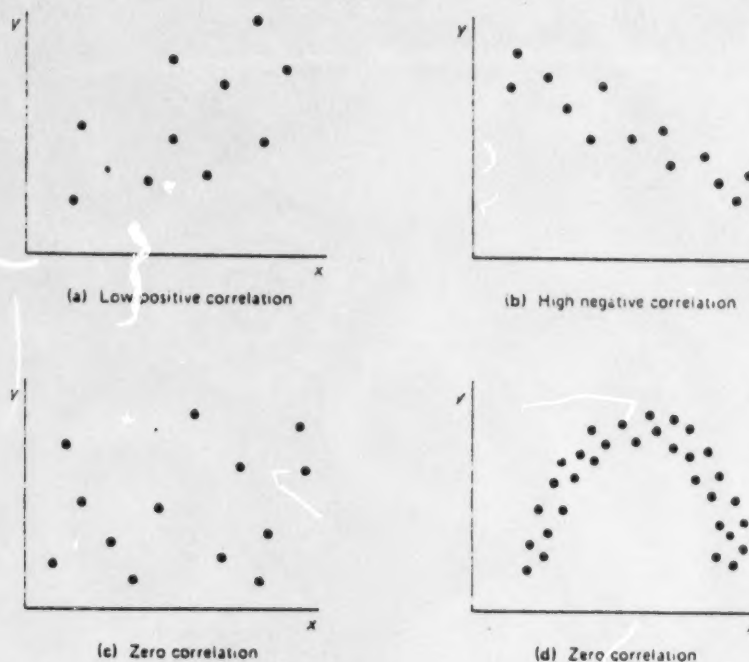


Figure 4.

Why do we emphasize the linear features of scattergrams? Because we are looking for a mathematical model to represent the data and a straight line is the simplest model. Moreover, by finding the equation of the line which best fits the data, we can predict approximately what value of y will turn up given a particular value of x . (See the dotted line in figure 1.)

A criterion for the "best" line. What shall be the criterion for the line which best represents the observed data? Remember, that we intend to use the line to predict a final grade from a preliminary score. Remember also, that this data was based on a random sample so we have no reason to give more importance to one point than another. Thus the "best" line might be as drawn, roughly midway between each pair of points.

ELECTRIC CIRCUITS THAT DON'T SHOCK

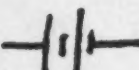
Introduction

This is an exercise dealing with electric circuits. You will learn how to connect simple circuits and make measurements of electrical quantities. After the collection of information about the circuits, the objective will be to find relationships among the measurements, if they exist.

The explanations of the symbols in the diagrams are:
Measurable quantities

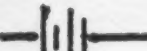
 Resistance

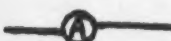
 Current

 Voltage

Symbol



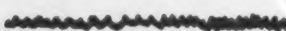












Circuit
Element

Resistor

power supply

Ammeter

voltmeter

Key (opened)

Slide-wire CONTACT

length of wire

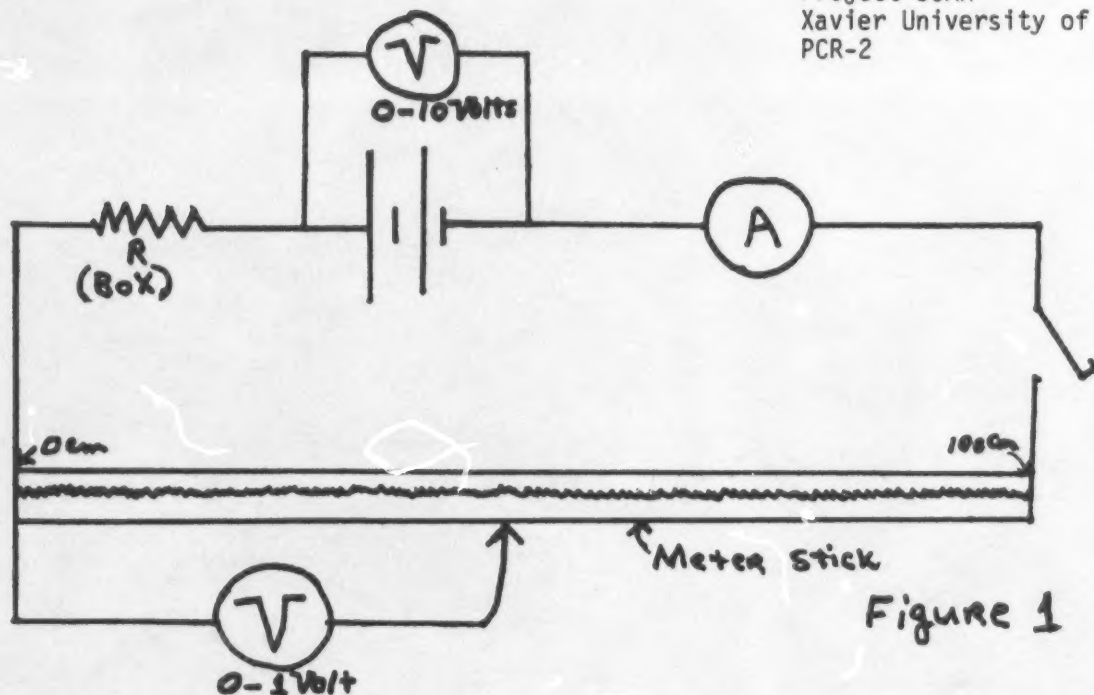
Materials and equipment needed:

- 1m lengths of different kinds of wire
- key
- power supply
- 1 milliammeter (0 - 250ma), 1 microammeter (0 - 100 μ a)
- 3 voltmeters: one 0 - 1-v, and two 0 - 10-v
- leads (connecting wires)
- resistance box (0-999)
- 2 C clamps
- meter stick

Exploration

In the first part of this exercise you will collect information about the circuit diagramed in figure 1 on the next sheet.

Select one of the lengths of wire given you and fasten its ends to the ends of a meter stick with your C clamps. The wire should lie along the length of the meter stick as shown in the figure. See if you and your partner can connect the circuit as diagramed. You may seek help from your neighbors and/or the laboratory instructor in order to put the circuit together correctly.



IMPORTANT THINGS TO REMEMBER!!

DO NOT plug in and turn on the power supply UNTIL the instructor checks your connections.

AT ALL TIMES a value greater than 12- Ω must be kept dialed on the resistance box, and the power supply MUST NOT be increased above 6.0-volts. The voltmeter connected directly to the power supply will indicate its voltage.

The slide-wire contact may touch the wire at any point on the wire between the "0" and "100"cm positions.

CONSULT THE CHALKBOARD FOR ADDITIONAL INSTRUCTIONS!!

.....

With the help of your partner, decide on what you think the measurable quantities of the circuit are. Write them at the heads of the columns in Table 1.

(On the following pages, you are to construct your own Tables 1 through 4 in the spaces provided for them.)

TABLE 1

Consult the persons working nearest you and see if they have identified any quantities which you may have overlooked. If they have such quantities, you may write them in your table.

Now that the measurable quantities have been identified, discuss with your partner how each of them is measured. Here again, you may seek the help of your neighbors.

Finally, discuss the making of the measurements with the instructor. Also, be sure that you know how to read each meter before you begin taking measurements.

Dial a value (greater than $12\text{-}\Omega$) on the resistance box and plug in the power supply. Turn the knob on the power supply only slightly and close the key by pressing it down. Check to see that all meters are working and connected correctly. If needles of meters move or attempt to move to the left of zero, they are connected incorrectly.

What are the quantities that you can physically, independently change in your system?

Select one of these quantities to be the one that you will independently change in this first set of measurements. Decide on a systematic procedure in which to take measurements of all quantities that you have identified. Make these measurements and record their values in Table 1.

Now select one of the other quantities that you can independently change. You are ready to acquire another set of data by making measurements all over again. Take these measurements and record your data in Table 2.

TABLE 2

Now choose another quantity that you can independently change. You are ready To acquire another set of data by taking another set of measurements. Make these measurements and record their values in Table 3.

TABLE 3

Invention

Starting with Table 1, find as many relationships among quantities as you can in each table. After you are certain (What can you do with the data to be certain of a relationship?) That the suspected relationships actually exist, write them in the table space below, and explain your proof for each relationship.

Application

Using one of the cylindrical resistors as R , connect the circuit shown in figure 2.

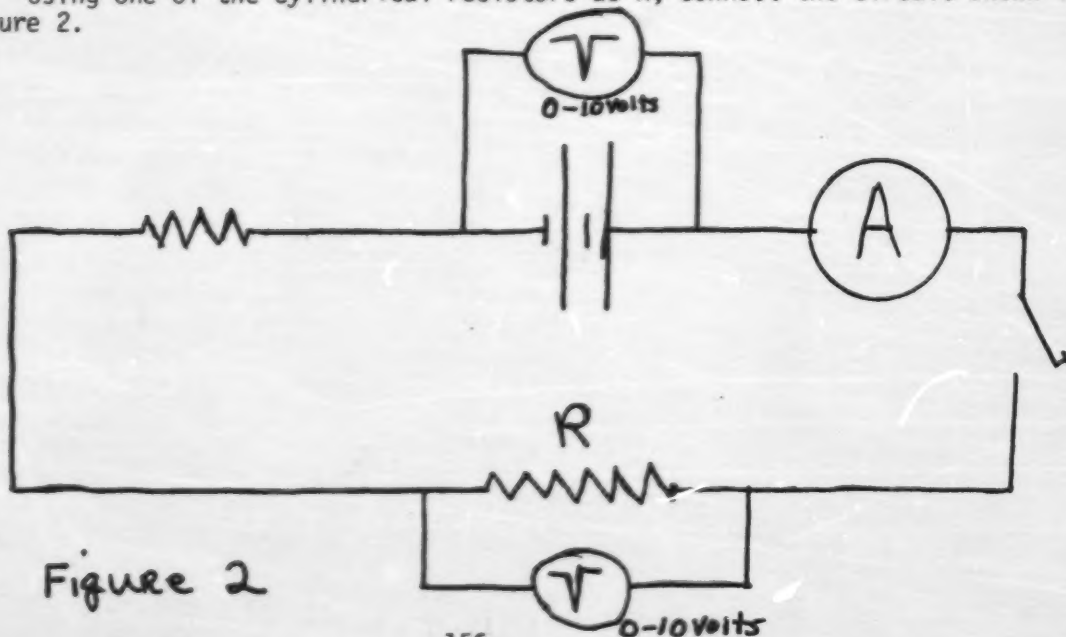


Figure 2

The numerical value of the resistance of each resistor is given by the color band near one end of the resistor. The first color represents the first digit in the number, and the second color represents the second digit. The third color represents the factor of 10 by which the first two numbers are to be multiplied. The fourth color represents the tolerance, or percent error of the value.

RESISTANCE COLOR CODE

- 0 Black
- 1 Brown
- 2 Red
- 3 Orange
- 4 Yellow
- 5 Green
- 6 Blue
- 7 Violet
- 8 Gray
- 9 White

Tolerance:

- Gold..... $\pm$ 5%
- Silver..... $\pm$ 10%
- No fourth band.... $\pm$ 20%

In Table 4 below, list the resistors given you for this part of the exercise by their color bands and resistances. Also in Table 4, you should provide for the other quantities to be measured or calculated.

TABLE 4

For this part of the exercise you MUST KEEP THE POWER SUPPLY VOLTAGE SET AT 1.0- VOLT.

Discuss briefly with the instructor the quantities that you wish to measure.

When granted permission by the instructor, perform a set of measurements and record the information in Table 4.

Search for relationships among the quantities recorded. On the data, you may perform whatever operations you wish in order to discover these relationships. When you have verified the relationships, state them (with your proof) in the space below.

Attempt to formulate a mathematical equation for each of the relationships discovered in this (Application) and the other part (Invention) of the exercise.